Flexible Base Selection Guide

Initial Development of Texas Base Specifications

The Department first introduced flexible base Grades 1, 2, 3, and 4 into its Specifications in the *1962 Standard Specifications for Road and Bridge Construction*. The triaxial classification, minimum strengths at 0 and 15 psi lateral pressure, wet ball mill (WBM), and tighter gradation bands were considered to be quite revolutionary for the time and reflected the new, scientific approach being taken for designing base. The goal of these new requirements was to obtain a more consistent, stable base layer.

The early stages of development of triaxial classification criteria for Grades 1–4 borrowed the Mohr failure envelope and criteria from classical geotechnical theory. Development of the classification curves customized the method to actual Texas base material performance. The classification curves, shown in Tex-117-E, were derived by calculating minimum shear strengths for materials identified by engineers as having similar field performance. Built into this method was a means to ensure that materials met minimum strength requirements to prevent bases from becoming unstable under any applied load.

Department engineers also recognized that aggregates varied from source to source, and that this affected performance. Many sources produced hard rock and silty fines. Others were not able to produce enough fines to bind the material together. Still other sources contained softer aggregates that produced large quantities as well as "stickier" fines. Soft rock particles caused problems because they degraded excessively during shipping and handling. After much research, it was determined that the strength requirement at 0 psi lateral pressure could differentiate materials containing various amounts of soft aggregate. Material that would meet the Grade 2 requirement but not the Grade 1 requirement was considered to have a higher risk of degradation during shipping and handling.

Evolution of Texas Base Specifications

Although it has long been recognized that gradation has significant effect on density and strength and that these are important characteristics of flexible base, recent forensic and research studies have reinforced that other parameters also impact its performance as a structural layer. These recent studies have shown that the type and quantity of the fine aggregate in a flexible base directly impacts the cohesiveness, stability, and sensitivity to moisture of the material. Base materials containing coarse aggregate particles that are hard can have stability problems because either they do not have enough fines, or the fines they produce do not have enough "stickiness" to bind the material together. In an unconfined state, these materials may not give acceptable performance; in a confined state, however, these same materials can perform very well. On the other hand, base materials containing coarse aggregate particles that are soft can produce large quantities as well as "stickier" fines. While these materials can provide a stable material in an unconfined state, they also have a stronger affinity for moisture and become weak when they get wet, often resulting in poor performance. As a result, what may appear to be an excellent material at low confinement pressures at optimum moisture may actually be a poor material when there is a slight increase in moisture. Conversely, material performing poorly at low confinement pressures may perform extremely well at higher confinement pressures, even when moisture has been introduced—this as a result of less fines, or the fines being comprised of crushed materials that are less plastic.

Although the fine aggregate fraction dictates base cohesiveness, the need for a flexible base to provide its own stability is dependent upon the pavement structure. Wheel load stresses are distributed and reduced with depth. The thicker the surfacing, the lower the stress is at the surface/base interface as well as in the base. Shoulders play a significant role because they provide lateral confinement. When shoulders are present, the base material obtains much of its stability from the edge confinement provided by the shoulders rather than from its fine aggregate fraction. When shoulders are not present, the base must obtain much of its stability and cohesion from its fine aggregate fraction.

The attached special provision is a simplification of base requirements. The most stringent of the current specification requirements for base, in Item 247, is to meet both classification and strength requirements at the 0 psi and 15 psi confinement pressures. Since a linear fit of the Class 1 and interpolated Class 2.3 curves is about the same as the envelopes defined by the two strengths at 0 psi and 15 psi for the two Grades of base, it is reasonable to simplify the requirement to include only the unconfined strength (UCS) and strength at 15 psi lateral confinement. The special provision removes the classification requirement (unless otherwise shown on the plans) but retains the strength requirements. Grade 1 base requires the material to have a minimum UCS of 45 psi and minimum 175 psi at 15 psi confinement. Grade 2 base requires a minimum UCS requirement of 35 psi and minimum 175 psi at 15 psi confinement. We believe that the material quality is not appreciably different without the classification requirements, and it reduces testing and sampling as an added benefit.

Making a similar arguments in the analysis of the Grade 5 requirements in the attached special provision, the Mohr-Coulomb failure envelope is very close to the failure envelope of materials meeting a Grade 2 requirement (Class 1.0 – 2.3), but under higher confining pressures, Grade 5 materials may exceed the strengths of materials that meet the minimum requirements for Class 1.0. The advantage of requiring strength at 3 psi confinement is to allow for materials that do not have a high cohesion or high UCS, owing to a lack fines brought about by "stickier" fines, but have strengths as high or exceeding both Grade 1 and Grade 2 materials at higher confinement pressures. In effect, the material can be a highly frictional material that may have more superior deformation resistance under repeated loads.

Flexible Base Descriptions

Grade 1

When there is little confinement, a base material must provide its own stability; hence, it is recommended for situations that do not provide stability from the pavement structure. When there is no lateral support or confinement, the base may become unstable as vertical load is applied. In this case, the base must provide its own cohesion and stability.

We need inherent stability because an unstable base, particularly when there is no lateral confinement, will deflect under even low traffic loads. Even up to 3 inches of hot-mix asphalt concrete will rut and crack from the deflections. In the case of low confinement or low lateral support, Grade 1 is more likely to protect the hot mix from failure at all levels of traffic. Grade 1 provides a uniform gradation but allows a higher minus #4 fraction than Grade 2. Grade 1 is best intended for use with thin surfaces, little or no confinement (no shoulders), and moderate to high traffic. Grade 1 will always meet Grade 2 requirements and almost always meet the requirements of Grade 5 in the attached special provision.

Grade 2

Grade 2 material can provide its own stability but to a lesser extent than Grade 1. It is a transitional base, in that it may or may not have high fines content and soft rock. Grade 2 allows for more gap-graded materials relative to Grade 1, as it can lack material in the coarse-sand gradation band (material passing No. 4 sieve and retained on No. 40 sieve). Grade 2 does allow a coarser gradation on the coarse-aggregate section of the gradation band (material retained on No. 4 sieve and larger). With Grade 2 materials, select applications where the material will be adequately confined to perform as a stable, high quality base. If Grade 2 material is adequately confined, it can achieve the strength levels of Grade 1 material. It may be less expensive than Grade 1. Districts may find that Grade 2 base satisfies a great percentage of their design needs.

Grade 3

Grade 3 base material is not recommended for base courses in pavement structures. This grade of material is primarily used for a subbase courses or maintenance uses, such as backfilling pavement edges, rehabilitation, or shoulder work. Consider using Grade 3 base only in the construction of very low volume roadways and only with adequate historical performance. There are occasions when projects have used local Grade 3 materials due to the lack of or expense of other base materials, and they have performed satisfactorily.

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. Consider adjusting material requirements in Grade 4 for the following reasons:

- **Roadways with low traffic loading (< 500,000 ESALS)**—Surfacing consisting of a seal coat or of hot-mix asphalt concrete 3 or more inches deep and with or without shoulders can specify a Grade 4 material with the gradation, plasticity index, liquid limit, nd WBM of Grade 2. A strength requirement is not needed when available local sources have a history of acceptable performance.

- **To improve the performance of mechanical properties (strength)**—An increased demand for performance from a base course may require increased restrictions. Additionally, Grade 4 specifications can add more stringent gradation, plasticity, or hardness requirements to increase the base strength and durability. This scenario can be useful for anticipated significant increases in traffic loading and when encountering weak subgrades. The use of higher quality bases can also reduce hot mix surface thickness and dissipate stresses more efficiently than regular bases, better protecting soft underlying subgrade soils

- **To design subbase materials in pavement structures for specific applications**—Some of these applications can include drainable or permeable subbase layers, separation layers, or PCC (rigid) pavement subbase layers.

Grade 5

Grade 5, shown in the attached special provision, allows harder rock with a lower fines content. Fines may be less sticky than those found in Grades 1 or 2. The material that meets this specification may have difficulty providing its own stability; therefore, it is recommended for situations where stability is provided from the pavement structure and roadway features (shoulders, surface thickness, or other material placed over it). Grade 5 base is a modification of a Grade 1 base and has most of its characteristics, except that it may or may not meet the UCS, 45 psi, for Grade 1 bases. The ability of the material to meet the UCS requirement is dependent upon the gradation and the constituents of the binder material. The compressive strength at 3 psi confinement is used for Grade 5 base requirements, since the Grade 5 base has the potential for having non-cohesive fines but has strengths equivalent to Grade 1 base when confined. Grade 5 base is not recommended for high traffic roadways with thin surfaces or when there are no shoulders, unless it is used as a subbase under an appropriate base and appropriate thickness.

Practical Construction to Meet Structural Requirements

Often the design of pavement structures and subsequent construction require thick base layers. A subbase in combination with a base can be used to satisfy these requirements. The subbase material may be a less costly base or one not otherwise recommended for use as a base. Whenever a base exceeds 12 inches, consider using a subbase. From a construction standpoint, to prevent excessive degradation of the material, a 5-inch course is the minimum subbase thickness recommended.

Although thick base sections are built to provide protection to the subgrade from frequent and heavy loads, structures must be constructed of bases with sufficient quality to resist deforming under loads. Triaxial classifications and minimum strength criteria have been used to ensure these materials are adequate for their applications. Research project 5562, "Guidelines for Using Local Materials for Roadway Base and Subbase," reaffirms the concept of providing bases with good internal friction and strength. The conclusions suggest discouraging the thickening of weak bases to prevent deformation and low strength, as it is ineffective. The research showed using weaker bases within 8–12 inches of the surface increases the potential to rut or become unstable and not properly support HMAC.

The construction of detours requires more pavement design and structural considerations than the application of stringent requirements for base selection—primarily because the service life is so much shorter. Most detours will only require properties of a Grade 2 base or a Grade 4 base with which the district has had good performance in similar circumstances.

Base Selection Factors

The base course in a pavement structure serves multiple functions, but the primary functions are to supply foundational support and capacity to the pavement structure, to provide a stable course to minimize flexural tensile stresses in surface layers, and to dissipate stresses induced by traffic loading to subbases and weaker underlying subgrades. The selection of an appropriate base material for a pavement structure is dependent on the overall interaction of the base course with the entire pavement structure. The grade of base is project specific; that is, there is a group of considerations that together must be evaluated. There is rarely a single driving variable that defines the base to use.

A rational process of selection should consider various factors that influence its accessibility and its performance. By defining variables that are common in a region, district, area, or county, a defined process may be established. Table 1 shows an example of a decision matrix to determine recommended base types. Development of local decision tables, matrices, charts, or systems are recommended.

Selection factors often considered include:

- **Availability and cost**—Availability and cost often dictate the selection of base materials in various areas with limited alternatives. Local sources may be the least expensive material and must be evaluated for strength and stability to support the loading conditions identified. If materials have to be imported, where transportation costs are substantial, specifying a high quality base may be justifiable.
- **Surface thickness**—The thinner a surface layer, the more stress is transferred to the base course, requiring higher performing strength properties and internal stability. Surface treatments are more pliable and tolerate surface deformations better than HMAC surfaces. In general, as the thickness of surface increases, the amount of stress on the base decreases, making the selection of a lesser quality of base more acceptable; however, where there are HMAC surfaces, particularly thinner sections, the base selected must be very sound and resistant to deformation, since even small deformations can cause the HMAC to develop fatigue cracking. As the thickness of the

surface increases, confinement of the material increases, allowing for bases that perform well in these circumstances.

- **Subgrade stiffness and strength**—Select the properties of a base to provide quality materials to reduce vertical stress applied to protect the subgrade, thereby preventing it from deforming/rutting/consolidating. Where thicker bases are required, subbases are often used as a lower cost alternative to supplying more expensive materials for the full depth of the base course.
- **Amount of lateral confinement**—Base material with low unconfined strength but good confined strength can benefit from the stability produced by the lateral confinement of pavement features such as shoulders, curbs, and other structures placed adjacent to base, preventing lateral displacement.
- **Traffic volume and loading**—The magnitude and amount of traffic loading (trucks in the ADT or Equivalent Single Axle Loads, ESALs) will determine the stresses induced and the performance of the pavement structure. High stresses induced by traffic loading may require a base with higher strengths. Materials with coarse aggregate gradations tend to resist repetitive load better than finer graded materials but often require more confinement to remain stable.

Base Selection Example

Table 1 shows an example flexible base selection chart that uses factors discussed previously. Although three decision factors were included in this table, more, fewer, or different factors may be included to define the base materials recommended for the application identified. The following may be incorporated to satisfy more appropriate local requirements:

- ADT (as a substitution or in combination with ESALs)
- Percent Trucks
- Load (average ten heaviest wheel loads daily - ATHWLD)
- Functional Class
- Highway Type (FM, SH, US, IH, etc)
- Base Type

The identification of "acceptable" base grades shown in Table 1 are only suggested grades and modifications to grades as a Gr4. Districts should review their own criteria and select the grade of base and base characteristics appropriate for their conditions. A Grade 4 base, such as that identified in the example, may be produced from local materials; however, the requirements selected for the acceptance of the material must be based on historically satisfactory performance.

The example, shown in Table 1, uses the following assumptions and notes:

a) Bases with requirements more stringent than the grade(s) listed are also acceptable for use; however, Grade 5 is not recommended for surface treatments with no shoulders;

b) Grades of base identified pertain to the requirements shown in the attached special provision; and

c) The performance of Grade 4 base, using Grade 2 requirements without minimum strengths, will perform satisfactorily for the application intended—identified by the Table 1 criteria.

Table 1—Example Flexible Base Selection Chart

Shoulder Width	Asphalt Surface Thickness	Traffic (Design ESALS)	Base Grades
<3'	Surface Treatment	< 500,000	4*
		> 500,000 and ≤3,000,000	2
		≥3,000,000	1
	HMA < 3"	<500,000	2
		>500,000 and ≤3,000,000	1
		≥3,000,000	1
	HMA ≥3"	< 500,000	4*
		> 500,000 and ≤3,000,000	2 or 5
		≥3,000,000	2 or 5
≥3'	Surface Treatment	< 500,000	4*
		> 500,000 and ≤3,000,000	2 or 5
		≥3,000,000	2
	HMA < 3"	< 500,000	4*
		> 500,000 and ≤3,000,000	1
		≥3,000,000	1
	HMA ≥3"	< 500,000	4*
		> 500,000 and ≤3,000,000	2 or 5
		≥3,000,000	2 or 5

* Grade 2 requirements without minimum strengths or classification.