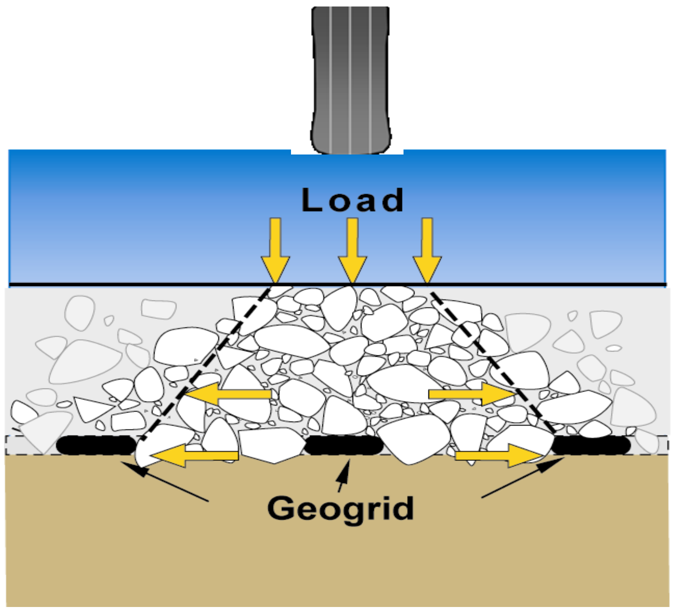
Aggregate Base Enhancement with Biaxial Geogrids

for Flexible Pavements

Guidelines for Project Selection and Design

October 20, 2012



Geosynthetics Subtask Group
Pavement Foundations Task Group, Rock Product Committee

California Department of Transportation
Pavement Program, Office of Concrete Pavements and Pavement Foundations

Disclaimer

This guideline has been adopted by the California Department of Transportation (Caltrans) for determining and using aggregate base enhancement biaxial geogrid practices on Caltrans owned roadways. Use by other agencies is at their discretion and should only be done after reviewing the facts and issues of their roadways. This guide does not supersede Caltrans or Federal standards, specifications, or regulations.

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1. Overview

This guide has been prepared to provide guidance for project selection and design of flexible pavement using aggregate base (AB) enhanced with a biaxial geogrid. Specific information is provided for types of geogrid used for structural enhancement of AB.

The basis of this guide is over 20 years of successful geogrid use on California highways, Federal Highway Administration (FHWA) guidance, Association of State Highway Transportation Officials (AASHTO) accepted design practices, technical information from the geogrid manufacturers, and results from full scale accelerated pavement testing (APT). It is based on the best information available at the time this guide was written. As products improve and more information becomes available, modifications to this guide may be made.

2. Aggregate Base Enhancement with Biaxial Geogrid

Biaxial geogrids are geosynthetic materials formed into a grid of integrally connected tensile elements. It has apertures of sufficient size to allow "strike-through" and interlocking with surrounding aggregate base materials. Biaxial geogrid increases the stiffness of unbound aggregate base layers and confines the aggregate particles under repetitive loading.

Biaxial geogrids must be punched and drawn polypropylene material and comply with Caltrans' Standard Specifications, Section 88-1.02P (Biaxial Geogrid).

Biaxial geogrids are placed either below or within the aggregate base layer of a pavement structure. The composite section consisting of the geogrid and aggregate base is often referred to as a mechanically stabilized layer (MSL). A schematic of a typical asphalt pavement section enhanced with a biaxial geogrid is shown in Figure 1. Additional reading materials on the topic may be found in the list of references provided in Appendix D.

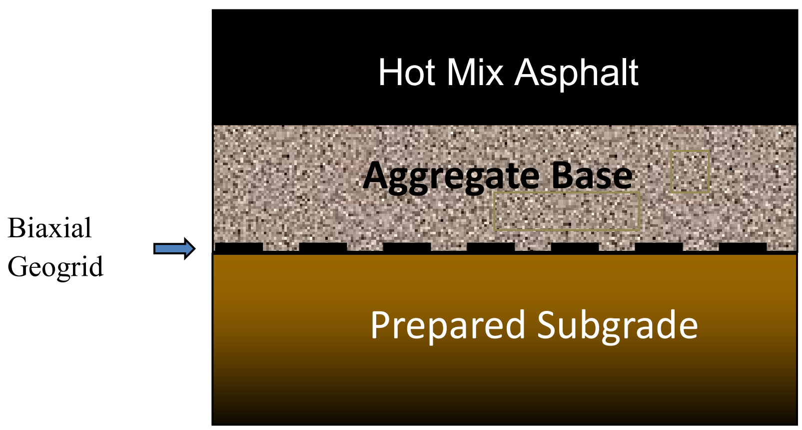


Figure 1. Typical biaxial geogrid application

Biaxial geogrid benefits include:

- Reduced aggregate base thickness, which may provide immediate cost savings
- Increased performance life and reliability of the pavement
- Improved compaction and uniformity over soft or variable soils
- Reduced hauling and heavy construction truck traffic on local roads due to relatively less materials required for removal or replacement or backfill
- Ability to install the product in a wide range of weather conditions

- Can be used with reclaimed asphalt concrete aggregate base
- Improved safety due to reduced construction time from reduced hauling and processing of subgrade or backfill materials

3. Appropriate Applications

Biaxial geogrids are intended for asphalt (flexible) pavements. At this time, there is no known benefit for using biaxial geogrids under concrete pavement. Biaxial geogrids can be used for a variety of project conditions, but it is most cost effective in areas where pavement surface grade and drainage control the pavement structural section. Appropriate applications include:

- Restricted pavement surface grades due to local drainage or vertical clearance. A biaxial geogrid can provide a thinner section with performance equivalent to a pavement with a thicker aggregate base.
- Expedited construction is required. The thinner biaxial geogrid section will result in less construction time due to less material being required. In many cases biaxial geogrid also results in less compaction effort.
- Increased pavement structural capacity and performance life for the same thick pavement section without biaxial geogrid.
- Soft or weak subgrades are encountered. Biaxial geogrids can reduce or eliminate the amount of materials that need to be removed.

4. Limitations

The following conditions are generally not suitable for use of biaxial geogrids:

- Subgrade with R-value greater than 40. The structural enhancement contribution from biaxial geogrids will be relatively small and uneconomical.
- Subgrade stabilized with lime or cement. The stabilized subgrade will be relatively stiffer and structural enhancement contribution from biaxial geogrids will be relatively small and uneconomical.
- Unsuitable subgrade materials as defined in the Standard Specifications, Section 19-1.01B.

Proposed uses beyond the applications and limitations stated above are considered to be experimental and will require the HQ Pavement Program's approval in accordance with HDM Topic 606.

5. Project Evaluation

A comprehensive project evaluation is important to understand the constraints of pavement design including drainage, pavement finish surface grade, and existing subgrade conditions. Generally, existing drainage and subgrade conditions will dictate the type and thickness of the pavement structure.

5.1 Subgrade Materials Sampling and Testing

Subgrade material samples should be collected from the proposed pavement alignment section or for the existing pavement from the edge of the road to determine gradation, Atterberg limits, and R-values. Samples should be collected from alternate sides of the road at 1,500 ft intervals. For the existing pavement, sample locations should be as close to the edge of the road as possible, while ensuring that base and subbase materials are not included in the collected sample.

5.2 Subgrade Evaluation

Standard materials tests are required to determine the characteristics of the existing subgrade and assess the appropriate use of biaxial geogrids in the pavement section. The laboratory testing required for the subgrade and aggregate base materials is presented in Table-1.

Table-1: Laboratory Tests Required for Subgrade and Aggregate Base Materials.

Testing	Caltrans test method	Acceptable value for biaxial geogrid use
R-value of subgrade	CT 301	R-value < 40
PI (Plasticity Index)	CT 204	PI <12
Gradation of subgrade and aggregate base	CT 202	See Section 5.3 of this Guide

5.3 Project Evaluation Summary

The project evaluation should be summarized with respect to the existing drainage conditions, designed pavement finished grades, and subgrade conditions. For the subgrade, consider the following in the evaluation summary:

- Do not use a biaxial geogrid when the R-value of the subgrade is greater than 40. The structural enhancement to the aggregate base will be relatively minor.
- For subgrade comprised of clay soils with a PI greater than 12, use an engineering alternative according HDM Section 614.4 to compensate for potentially expansive soils. In the case of thicker pavement sections designed to counteract expansive pressures, the use of a thinner geogrid-enhanced section may not be appropriate as swelling of subgrade may be relatively high due to a reduced surcharge loading.
- If subgrade enhancement geotextile (SEG) is used, application of filter fabric is not required. The geotextile will provide filtration and separation between subgrade and aggregate base.
- Fine materials in subgrade can migrate upward into the base layer and leave voids that result in settlement. To control this, a layer of filter fabric should be placed at the subgrade-aggregate base interface (below the biaxial geogrid). To make this decision, the gradation of the subgrade should be evaluated, and if necessary, compare to the specified aggregate base gradation. If the subgrade is coarse consisting of material with less than 50 percent passing the No. 200 sieve, filter fabric is not required. If the subgrade has more than 50 percent passing the No. 200 sieve, compare the subgrade to the specified aggregate base and determine if the condition:
    - $D15_{\text{Aggregate Base}} / D85_{\text{Subgrade}} > 5$ is met. If so, specify the filter fabric. See Figure 2 for determining filter fabric application.
- If imported borrow is used for subgrade construction, always use filter fabric. The application of filter fabric will minimize potential contamination of the aggregate base from the imported borrow. It is difficult to determine the source of borrow locations.

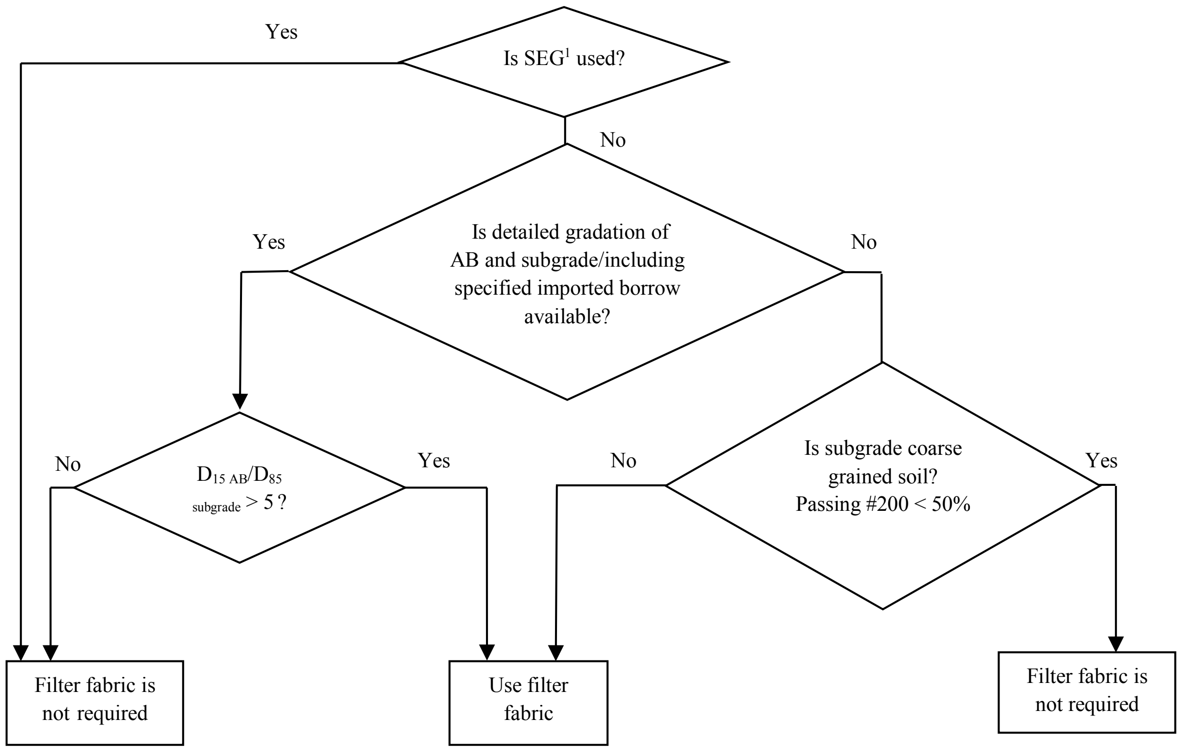


Figure 2. Flowchart for Determining Filter Fabric Application
Note 1. Subgrade Enhancement Geotextile (SEG)

6. Design

The typical design steps for asphalt (flexible) pavements are:

1. Assess the applicability of using biaxial geogrids.
2. Determine aggregate base thickness for the flexible pavement section without biaxial geogrids using the methods discussed in the Caltrans Highway Design Manual.
3. Use Table 2 below to determine the reduced aggregate base thickness based on the presence of a biaxial geogrid within the pavement section. This involves the use of Aggregate Base Reduction Factors (ABRF's) summarized in Table 2 based on the effective R-value of the subgrade.
    - Evaluate the subgrade for possible inclusion of filter fabric as explained in Section 5.3 and Figure 2 above.
4. Investigate the potential economic benefits of using biaxial geogrid enhancement and filter fabric, if required. If appropriate, consider adopting an alternative design.
5. Develop a pavement performance monitoring plan.

Table 2: Maximum Aggregate Base Thickness Reduction Factors of Asphalt Sections Enhanced with Biaxial Geogrids

Subgrade Effective R-value	Maximum % Reduction in AB thickness
R-value ≤ 20	25
$20 <$ R-value ≤ 40	20

Notes:

1. For AB thickness > 1.5 ft, add a 2nd layer of a biaxial geogrid. The upper layer must be placed at least a minimum of 0.5 ft beneath the final AB surface
2. The minimum AB thickness with enhanced biaxial geogrid included must be greater than or equal to 0.35 ft
3. Subgrade effective R-value is design R-value including R-value of subgrade after implementation of geotextiles.

7. Plans, Specifications, and Estimating

7.1 Plans

The layout plans should show the limits of the biaxial geogrid (width and length). The biaxial geogrid should be included as part of pavement structure sections used on the typical sections, layouts, and details sheets. The typical cross sections should clearly show the location of the biaxial geogrid and if used, the filter fabric, within the pavement structure. Example pavement cross sections with geogrid and filter fabric are shown in the Appendix C.

7.2 Specifications

Include Standard Special Provision 26-1 for the biaxial geogrid enhanced aggregate base. This specification addresses material property requirements, construction methods, inspection, acceptance requirements, measurement, and payment.

7.3 Estimating

The estimating for the biaxial geogrid enhanced AB must take into account furnishing and installation of biaxial geogrid in addition to the standard estimating for AB.
The biaxial geogrid is measured by the square yard of the covered area and does not include biaxial geogrid required for overlaps.

7.4 Bid Item

Payment for geogrid-enhanced aggregate base should include furnishing and installation of the biaxial geogrid and, if used, furnishing and installation of filter fabric.

8. Additional Notes

- The geogrid material should be punched and drawn biaxial geogrid.
- Determine gradation of specified AB for the project.
- $D15_{\text{Aggregate Base}}$ can be determined from gradation plot. For accuracy, additional sieve sizes No. 50 and 100 may be required to determine $D15_{\text{Aggregate Base}}$..
- For ensuring performance, use filter fabric if the gradation of subgrade is not available or cannot be practically obtained.

APPENDIX A

Glossary of Terms

Accelerated Pavement Testing (APT): Application of wheel loads to specially constructed or in-service pavements in order to determine the pavement response and performance. Loading and response data are acquired in a very controlled way. Accumulation of data can be accelerated and gathered in a reasonable period of time.

Aggregate Base Reduction Factors (ABRF): Percentage of the base in an enhanced pavement, as compared to the base thickness in the un-enhanced pavement with the same material component.

Biaxial Geogrid: For the purposes of this design guide, biaxial geogrid is a punched-and-drawn polypropylene geogrid with rectangular or square apertures. Application of these products required 95% relative compaction of the subgrade for a minimum depth of 2.5 feet below finished grade.

D15: D15 is the sieve size represented by the "15 percent passing" point when conducting a sieve analysis.

D85: D85 is the sieve size represented by the "85 percent passing" point when conducting a sieve analysis.

Mechanically Stabilized Layer (MSL): A composite layer of a defined thickness comprised of unbound granular materials combined with one or more layers of geogrid. The combination of the two materials creates an enhanced composite layer that has improved pavement properties and performance capabilities.

Punched-and-Drawn Geogrid: An integrally formed geogrid that starts as a single sheet of extruded polypropylene and is then punched and stretched (or drawn) into a final product that comprises a regular network of open apertures.

Enhancement: The improvement of the soil system by introducing a geosynthetic to enhance lateral restraint, bearing capacity, and/or membrane support.

Separation: A geosynthetic function that prevents the intermixing between two adjacent dissimilar materials, so that the integrity of materials on both sides of the geosynthetic remains intact.

APPENDIX B

Examples for Biaxial Geogrid Design

Example-1:

<u>Project Description</u>: A new 5 mile flexible pavement section of two-lane state highway is designed for a 20-year service life. Traffic Index (TI) is 12. The subgrade has an R-value of 20. Project meets applicability requirements for biaxial geogrid.

<u>Design Steps:</u>
Design flexible pavement section using HDM Section 6.3.3.1 (or using any other approved design method including the mechanistic-empirical method). For illustration purposes, HDM Section 6.3.3.1 is used in this example. Filtration and swelling of subgrade materials are not issues and thus were not considered.

STEP 1. Design of the Pavement Section

GE required = 0.0032× (TI) ×(100-R) = 0.0032×(12)×(100-20) = 3.07 ft.

Assume pavement section of HMA over Class 2 AB (R-value = 78, Gf_{AB}= 1.1)
Minimum GE required over Class 2 AB = 0.0032 ×12×(100-78) = 0.845 ft.
Assume 0.7 ft. of HMA

$$\text{Gf for 0.7 ft. of HMA} = 7 \times \frac{(0.7)^{\frac{1}{3}}}{(12)^{\frac{1}{2}}} = 1.79$$

GE from 0.7 ft. of HMA over Class 2 AB = 0.7 × 1.79 = 1.25 ft. > 0.845 ft. ……. OK

$$\text{Class 2 AB thickness} = \frac{(\text{GE required – GE from HMA})}{Gf_{AB}} = \frac{(3.07-1.25)}{1.1} = 1.65 \text{ ft.}$$

Alternative	Design T.I.	Design R-value	GE Required (ft.)	GE Actual (ft.)	HMA (Gf)	AB Cl. 2 (Gf)	Design Section HMA (ft.)	Design Section AB Cl. 2 (ft.)
Unreinforced Section	12.0	20	3.07	3.07	1.79	1.1	0.70	1.65

STEP 2. Design Biaxial Geogrid Pavement Alternative

- Refer to biaxial geogrid Design Table 2 and use ABRF = 25% for the subgrade R-value = 20.
- The reduced AB thickness is:

Reinforced AB thickness = (1.65 × (1-0.25))
= 1.238 ft
Round to AB thickness = 1.25 ft

Alternative	Design T.I.	Design R-value	GE Required (ft.)	HMA (Gf)	AB reduction %	Alt Design Section	
						HMA (ft.)	Class 2 AB (ft.)
Biaxial Geogrid Max Thickness Reduction	12.0	20	3.07	1.79	25	0.70	1.25

- Biaxial geogrid placement: Refer to Table-2, note 3. Since alternate design AB Thickness < 1.5 ft, install only one layer of biaxial geogrid at the AB/subgrade interface.

Step 3. Cost Comparison

Construction Cost			
Material Type	**Cost ($/Ton)**	**Cost ($/CY)**	**Cost ($/ft×SY)**
Hot Mix Asphalt	85.00	186.00	62
Class II Aggregate Base	20.00	36.00	12
Biaxial geogrid	2.50/ SY		
Subgrade Excavation		10.00	3.3

Summary of Initial Cost Savings		
Expenses	**Unreinforced**	**Alt. Biaxial Geogrid Section**
HMA ($/SY)	$43.4	$43.4
Class 2 AB ($/SY)	$19.75	$14.88
Biaxial geogrid ($/SY)	n/a	$2.50
Subgrade Excavation ($/SY)	$7.75	$6.40
Total Unit Costs ($/SY)	$70.90	$67.18
Total Costs ($)[1]	$5,317,500	$5,038,500
% Savings	n/a	5.3%
Design Life Extension (Traffic Index)	12.0	12.0

Summary of Time Savings		
Expenses	**Unreinforced**	**Alt. Biaxial Geogrid Max Thickness Reduction**
Total Aggregate Base (CY)	41,250	31,250
# of Trucks Loads	3,438	2,604
# of Truck Loads Saved	0	833
# of Reduced Truck Load Hours[3,4]	0	625

Note:
1. Total Area = 75,000 SY (5 miles, 26' wide)
2. Assuming average truck carries 12 CY of Aggregate Base. Both undercut trucks and aggregate base trucks saved
3. Assuming 1 hour round trip per load (from aggregate base source to site) – geogrid installation time (15 minutes for equivalent surface area covered by 12 cubic yard of AB).
4. Additional time is saved from the elimination of the compaction and testing which is otherwise required for the additional lift of AB.

Example-2:

Project Description: A new 5 mile flexible pavement section of two-lane state highway is designed for a 20-year design life. The subgrade has an R-value of 10. Traffic Index (TI) is 12. Project meets applicability requirements for biaxial geogrid.

Design Steps:

Alternative-1: Design flexible pavement section as illustrated in Example-1 for the subgrade R-value of 10.

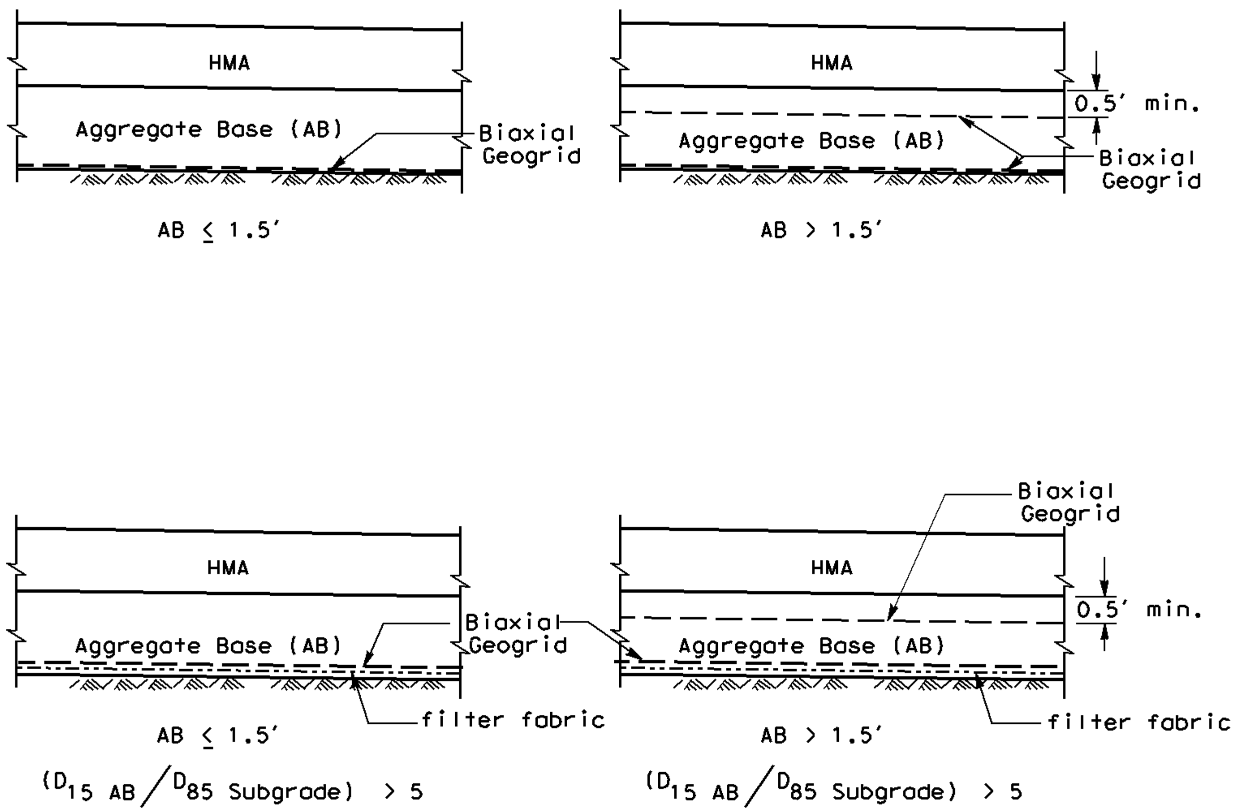
Alternative-2: Consider use of subgrade enhancement geotextile (SEG). The R-value of subgrade can be increased to 20 as defined in Subgrade Enhancement Guide. Hence, use effective or design R-value of 20 for the flexible pavement design. Use effective R-value of 20 for choosing reduction factor from the Table 2.

Design steps:

1. Follow design example-1
2. For the cost comparison include cost of SEG including installation.
3. For the time saving, include SEG installation time.

APPENDIX C

Example Pavement Sections



**TYPICAL FLEXIBLE
PAVEMENT SECTIONS
Not to scale**

APPENDIX D

References

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