MSCE in Energy Infrastructure

Brief on Pavements for Project Access

MSCE Energy Infrastructure Brief on Pavements for Project Access

Topics

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- Gravel surfaced vs paved surfaces
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Introduction

This brief will cover the basics associated with project road pavement types and a limited treatment of geometric considerations. The focus is on low volume roads typically associated with energy projects. It is important to know that low volume roads implies a low number of vehicle passes; although, a few passes of heavy vehicles can be accommodated for project construction and maintenance operations.

Project roads are commonly privately owned. Since the data is available, about 77% of all roads in the US are owned by mostly local governments and these roads are like those used for project access. It also helps to know of all the roads in the US (all traffic levels) 94% are surfaced with a bituminous surface (with a chip seal or HMA).

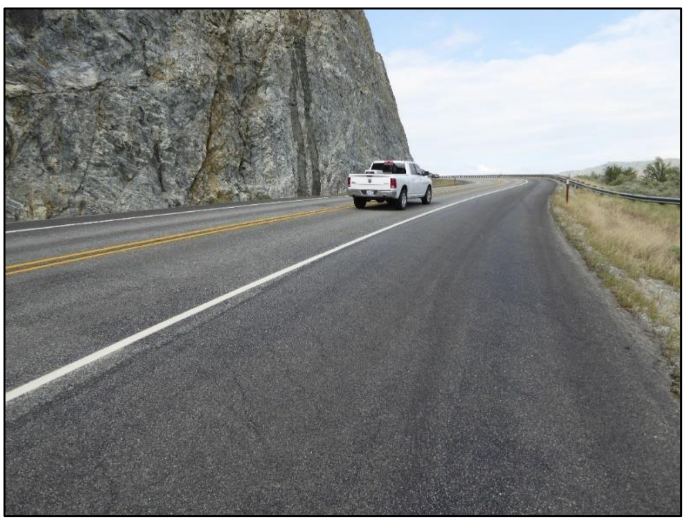
These are the types of roads of interest in this Brief. Photo courtesy of Kiewit Wind.

This road is a high-volume primary state highway and not discussed in this Brief.

There are two types of flexible pavements of specific interest for energy-related projects: (1) gravel surfaced roads, and (2) bituminous surfaced with either a chip seal or HMA surface. Illustrations of both major types follow below including a simplified cross-section.

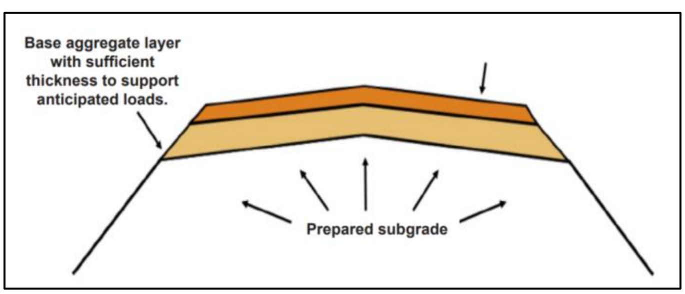
A gravel surface road in good condition. The primary load supporting portion of the structure is crushed stone.

Photo source: “Gravel Roads—Construction and Maintenance Guide,” FHWA, August 2015



A chip seal surfaced flexible pavement with a 6% grade. The photo is of a state highway; hence, the wide shoulders.

Photo: Joe Mahoney



This simplified cross-section of a flexible pavement shows three layers: (1) the upper layer—the wearing course which can be gravel or a chip seal or HMA, (2) a granular (aggregate) base course, and (3) the graded and compacted subgrade soil.

Figure source: “Gravel Roads—Construction and Maintenance Guide,” FHWA, August 2015

The photo below illustrates that gravel surfaces are widely used with energy related projects for work pads and associated access roads.

This photo shows a geothermal wellhead (under the geodetic dome) and associated piping. Gravel surfaces are used for the work pad and local access load. Gravel surfaces work well for locations such as these since traffic is limited but all-weather access is critical.

Geometric considerations include an introduction to typical road layouts which follow in the next section.

Geometric Considerations

AASHTO standards. A good source for road geometric criteria is the American Association of State Highway and Transportation Officials (AASHTO). AASHTO has two documents of special interest: (1) A Policy of Geometric Design of Highways and Streets, and (2) Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT ≤ 400).

From the second document (very low volume roads), it deals with traffic volumes and associated design guidelines on three traffic levels which are:

- 100 vehicles per day or less
- 100 to 250 vehicles per day
- 250 to 400 vehicles per day.

From both AASHTO documents, it is assumed that energy related project roads generally fall into the low volume categories.

County standards. Since many if not most energy infrastructure projects are located in rural areas, another important source on road standards includes the local county government. These standards contain reference to significant local practices…generally tied to national (AASHTO) or state standards.

Horizontal and Vertical Curves. The figure below shows a combination of horizontal and vertical curves (the Saddle Highway on the Big Island, Hawaii) with an HMA wearing course. Both horizontal and vertical curves will be described.

This well paved and maintained HMA surfaced road would typically not be acceptable for some energy related hauls (such is large, long turbine blades). However, it well illustrates two **horizontal curves** (both turning to the left), and **vertical curves** both **sag curves** (the dips) and **crest curves**.

Horizontal curves. An example is shown below.

This gravel surfaced road was created for a wind farm located in mountainous terrain and well illustrates **horizontal curves**. There are five in the photo. Why five? The number of curves **minimizes** the cut and fill in creating the road grade and the grade (or steepness) of the road.

This wind farm is located on flat terrain in South Texas. The road segments are generally straight with horizontal curves that provide direct access to each wind turbine. A clip from Google Maps illustrates a few of the road segments associated with this project.

Vertical curves. Examples follow.

This photo shows steam lines from geothermal wells along with a gravel surfaced road which was placed on top of the existing terrain to service the pipelines. There are minimal geometric design requirements for the gravel road since it simply follows the terrain.

A vertical curve on a mountain road. Note the cut section.

A vertical curve for an access road at a wind farm.

A combination of vertical and horizontal roads. The horizontal curves minimize the vertical curves which reduces cut and fill.

Gravel Surfaced vs Paved Surfaced

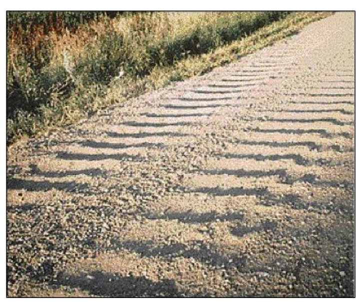
A basic question arises for project roads: should you use a gravel surface or a paved (bituminous) surface. There is information that can be helpful in making this type of decision and we will cover a few selected types. The rural roads being discussed can be defined by the following characteristics:

- Generally, only local traffic although truck volumes can be significant.
- Generally, provide access from commercial land use to the regional highway network.
- Roads are typically short in length and do not serve through traffic.

Additional information on gravel vs paved pavements can be helpful in making this type of decision such as:
- Expected average daily traffic
- Expected or maximum speeds affect geometric design considerations such as horizontal and vertical curves.
- User costs which are higher for gravel roads
- Terrain and potential for erosion
- Budget

A few comments on road surface longevity and maintenance:
- Gravel surfaced roads require annual maintenance which includes blading. There are additional issues such as (see figure next page):
    - Potholes
    - Corrugations
    - Dust
- Chip seal surfaced roads typically last from 7 to 10 years before resurfacing typically with another chip seal.
- HMA surface layers typically last from 15 to 20 years (the age range noted only applies to the HMA surface since you expect the remainder of the pavement structure to continue to function). Once the HMA surface deteriorates to unacceptable levels, it can be overlayed with more HMA or several other possible treatments.

Potholes. Causes include excess water and traffic. The combination removes fine materials from the surface gravel.



Corrugations. The 4 primary causes of corrugations in gravel roads: (1) driving too fast, hard braking), (2) lack of moisture in the surface gravel, (3) poor quality gravel, and (4) tire slippage on steep grades.

Dust. The amount of dust generated by gravel or unpaved road is a function of:
- Silt content of the surface material
- Weight of the vehicles using the road
- Gravel mixture content (%), and
- Vehicle speed.

Pavement Thicknesses

There are three ways to design or select a structural pavement system (for either gravel or bituminous surfaced pavements):

Experience: This assumes that someone has designed and built similar pavements and can apply their experience to this specific project. This is not recommended since site conditions vary from one project to another and even within a project.

Design catalogs: These are a collection of tables or figures which depict the types of layers and materials in a pavement and the associated thicknesses. Commonly, these catalogs are developed for associations that are involved in the paving industry. In the content which follows, the design catalog by AASHTO will also be presented.

Design procedures: These procedures provide more detail which consider site specific input for traffic, layer materials and the subgrade. There are various design procedures but know that civil consulting firms, if tasked with pavement designs for a project, will use a formal design procedure. We will briefly illustrate the AASHTO 93 Flexible Design Procedure.

AASHTO Design Catalog. The AASHTO design catalog focuses on low-volume roads such as those typically associated with energy infrastructure related projects. The process is reasonably detailed and include selection of climate region, traffic levels (in terms of design ESALs), subgrade support, and conversion of Structural Number (SN) to layer thicknesses. For this Brief, detailed design is not appropriate; however, a key AASHTO catalog table is shown below:

Table 4.7. **Flexible Pavement Design Catalog for Low-Volume Roads: Recommended Ranges of Structural Number (SN) for Six U.S. Climatic Regions, Three Levels of Axle Load Traffic and Five Levels of Roadbed Soil Quality— Inherent Reliability: 75 percent**

Relative Quality of Roadbed Soil	Traffic Level	U.S. Climatic Region					
		I	II	III	IV	V	VI
Very good	High	2.6–2.7*	2.8–2.9	3.0–3.2	2.4–2.5	2.7–2.8	3.0–3.2
	Medium	2.3–2.5	2.5–2.7	2.7–3.0	2.1–2.3	2.4–2.6	2.7–3.0
	Low	1.6–2.1	1.8–2.3	2.0–2.6	1.5–2.0	1.7–2.2	2.0–2.6
Good	High	2.9–3.0	3.0–3.2	3.3–3.4	2.7–2.8	3.0–3.1	3.3–3.4
	Medium	2.6–2.8	2.7–3.0	3.0–3.2	2.4–2.6	2.6–2.9	2.9–3.2
	Low	1.9–2.4	2.0–2.6	2.2–2.8	1.8–2.3	2.0–2.5	2.2–2.8
Fair	High	3.2–3.3	3.3–3.4	3.4–3.5	3.0–3.2	3.2–3.3	3.4–3.5
	Medium	2.8–3.1	2.9–3.2	2.7–3.3	2.7–3.0	2.8–3.1	3.0–3.3
	Low	2.1–2.7	2.2–2.8	2.3–2.9	2.0–2.6	2.1–2.7	2.3–2.9
Poor	High	3.5–3.6	3.6–3.7	3.7–3.9	3.4–3.5	3.5–3.6	3.7–3.8
	Medium	3.1–3.4	3.2–3.5	3.4–3.6	3.0–3.3	3.1–3.4	3.3–3.6
	Low	2.4–3.0	2.4–3.0	2.5–3.2	2.3–2.8	2.3–2.9	2.5–3.2
Very poor	High	3.8–3.9	3.8–4.0	3.8–4.0	3.6–3.8	3.7–3.8	3.8–4.0
	Medium	3.4–3.7	3.5–3.8	3.5–3.7	3.3–3.6	3.3–3.6	3.4–3.7
	Low	2.6–3.2	2.5–3.3	2.6–3.3	2.5–3.1	2.5–3.1	2.6–3.3

*Recommended range of structural number (SN).

This AASHTO table considers the following:

- Subgrade support (shown as Relative Quality of Roadbed Soil
- Traffic level
- Climate regions, and
- Reliability level.

There are details associated with each input so the process is not as simplistic as it might appear.

AASHTO 93 Flexible Pavement. The design process is like the process briefly described for the AASHTO design catalog. It includes requirements on (1) selection of a pavement design life, (2) selection of the design reliability, (3) traffic loading over the duration of the design life (in terms of equivalent single axle loads (ESALs), (4) selection of the initial serviceability index (following new construction) and the terminal serviceability index (essentially an estimate for "end of life," (5) material layer coefficients, and (6) the strength or stiffness of the supporting subgrade soil (characterized as M_R by AASHTO).

The design process has been incorporated into computer programs and now free, available apps such as PaveXpress (http://app.pavexpress.com/#/). All design-related inputs are important but there are two the designer should pay extra attention: ESALs and M_R. The other inputs have ample recommendations that will assist in selection.

For rural access road locations associated with energy infrastructure such as pipelines, transmission lines, wind and solar projects, the number and magnitude of vehicle loadings is typically modest…as least compared to state highways. The material selections typically conform to local or state standard specifications; hence, the layer coefficients are straightforward to select. The subgrade prepared for placement of the aggregate base and surface layers (a chip seal or HMA) can be characterized by basic tests associated with either laboratory or on-site field tests. A common laboratory test is the California Bearing Ratio (CBR). Common field tests include results from a Dynamic Cone Penetrometer (DCP) or a Falling Weight Deflectometer. A excellent reference with additional detail about materials properties including the **subgrade** is the Pavement Interactive (https://pavementinteractive.org/reference-desk/design/design-parameters/subgrade/).

The design process results in a Structural Number (SN) which is converted to layer thicknesses by use of the layer coefficients. The basic relationship is: $\mathbf{SN = a_1D_1 + a_2D_2 + a_3D_3}$ which represents a three-layer pavement structure over the compacted subgrade.

Typical results from use of the AASHTO flexible pavement design process are shown below. The specific inputs included:

- Initial PSI = 4.5
- Terminal PSI = 2.0
- M_R: selected a subgrade a CBR = 5 (or a M_R a bit more than 7,000 psi)
- Layer coefficients of 0.44 for HMA and 0.14 for unstabilized aggregate base
- Fixed aggregate base thicknesses of either 6” or 8”
- Various levels of ESALs ranging from a value of 50,000 ESALs to a high of 500,000 ESALs.

The summary shows both the required minimum SN and the final SN once layer thicknesses are rounded and the final HMA and base course thicknesses.

ESALs	Base Thickness	SN and Final Thicknesses via PaveXpress			
		SN_{min}	SN_{final}	HMA	Base
50,000	8.0"	1.74	2.22	2.5"	8.0"
	6.0"	1.74	1.94	2.5"	6.0"
100,000	8.0"	1.95	2.44	3.0"	8.0"
	6.0"	1.95	2.16	3.0"	6.0"
250,000	8.0"	2.25	2.66	3.5"	8.0"
	6.0"	2.25	2.38	3.5"	6.0"
500,000	8.0"	2.50	2.88	4.0"	8.0"
	6.0"	2.50	2.60	4.0"	6.0"

HMA thicknesses require some judgment. Thicknesses of 2" or less can result in early failures. Some agencies specify minimum HMA thicknesses for low volume roads and streets ranging from about 3" to 5" to ensure a long life and limited road maintenance.

Useful Websites

- AASHTO Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT ≤ 400): www.transportation.org
- WAPA Pavement Guide: https://www.asphaltwa.com/
- WSDOT Pavement Policy: https://wsdot.wa.gov/engineering-standards/all-manuals-and-standards/manuals/pavement-policy
- PaveXpress: http://app.pavexpress.com/#/
- Pavement Interactive: https://pavementinteractive.org/
- UW MSCE Energy Infrastructure, https://www.energy-infrastructure.uw.edu/