US Army Corps
of Engineers
Afghanistan Engineer District

# AED Design Requirements:

## CERP Road - Geometric Requirements and Flexible Pavement Section Design

Various Locations,
Afghanistan

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AED Design Requirements
CERP Road Design

**1. General**

The purpose of this document is to provide design requirements as well as examples to Engineers, Project Mangers and Contractors for projects requiring the design and construction of Commanders' Emergency Response Program (CERP) Roads. This document will focus mainly on the selection of geometric parameters and the design of flexible pavement section; however other elements of roadway design will be mentioned as well. The reader is encouraged to review other technical manuals for in depth discussion. All units and examples in are in English units and metric conversion is shown as much as possible.

**2. Geometric Design Criteria**

CERP roads will normally be designed as aggregate surfaced roadway; with hot mix asphalt (HMA) placed depending on flexible-pavement systems. The design procedure involves determining if the roadway will be designated as a Class 1 or 2 roadways. This is based upon the average daily traffic (ADT) - number of vehicles passes per day. This data will not be readily available. If the ADT data is not available, then a determination will have to be made by the customer to classify the road as being either a Class 1 or 2. Below is the geometric design data.

Table 1 Geometric Design Data

| **DESIGN CONTROLS AND ELEMENTS** | CLASS 1<br>(2 LANE) | CLASS 2<br>(1 LANE) |
|---|---|---|
| **DESIGN CONTROLS** | | |
| 1. TRAFFIC COMPOSITION | | |
| Average daily traffic (ADT) (45% trucks) | 200-935 | <200 |
| Design hourly volume (DHV) | 30-140 | <30 |
| 2. DESIGN SPEED (V) MPH, (kph) | 40 (64) | 30 (48) |
| **CROSS SECTION ELEMENTS** | | |
| 3. ROADWAY | | |
| Min. Width - edge to edge, ft (m) | 23 (7) | 13 (4) |
| Normal cross slope % | 2 | 2 |
| 4. SHOULDERS | | |
| Each side | 3.3 (1) | 3.3 (1) |
| 5. BRIDGE CLEARANCE | Min Roadway wide + 0.75 m each side (for both classes of roads) | |

**ALIGNMENT ELEMENTS**

| | | |
|---|---|---|
| 6. SIGHT DISTANCE | | |
| Min. stopping sight distance, ft (m) | 275 (84) | 200 (61) |
| Min. passing sight distance, ft (m) | 1500 (457) | N/A |
| | | |
| 7. HORIZONTAL ALIGNMENT | | |
| Max. horizontal curvature | 14.5 deg | 36.7 deg |
| Pavement widening, ft (m) | 2 - 4 (0.6-1.1) | 2-5.5 (0.6-1.7) |
| | | |
| 8. VERTICAL ALIGNMENT | | |
| | | |
| Max. grade % | 10 | 15 |
| Critical Length, ft (m) | 450 (137) | 250 (76) |
| Min. grade % | 0.3 | 0.5 |
| | | |
| Crest Vertical curve k, ft (m) | 55 (16.7) | 35 (10.7) |
| Sag Vertical curve k, ft (m) | 55 (16.7) | 28 (8.5) |
| Absolute minimum length, ft (m) | 150 (45) | 100 (30) |

NOTES:

1 The DHV shown is total vehicles per hour for all lanes in both directions.
The DHV is approximately 15% of ADT

2 Critical length indicates the max. length upon which a loaded truck can operate
Without an unreasonable reduction in speed. Critical length may be increased
at an approximate rate of 50ft per percent decrease in grade from the values shown.

3 The minimum length of vertical curves are determined by multiplying "k" by the
algebraic difference in grades (in percent)

4 Turnouts will be provided at Class 2 roadways at every 400 meter intervals.

**3. Design Steps – Aggregate Surfaced Road**

The design of aggregate-surfaced roads is based upon placing high-quality material over top of the lower quality material which is placed on natural sub-grade to improve its strength. The materials should have greater strength than the sub-grade and should be placed so that the higher-quality material is placed on top of the lower-quality material. Sub-base and base-course materials should be tested for compliance with specification requirements for gradation, liquid limit (LL), plasticity index (PI), and California Bearing Ratio (CBR) values. When tests are completed, limiting conditions in the sub-grade and sub-soil must be determined. Materials are selected for each layer based on their characteristics (gradation, LL, PI and CBR values).

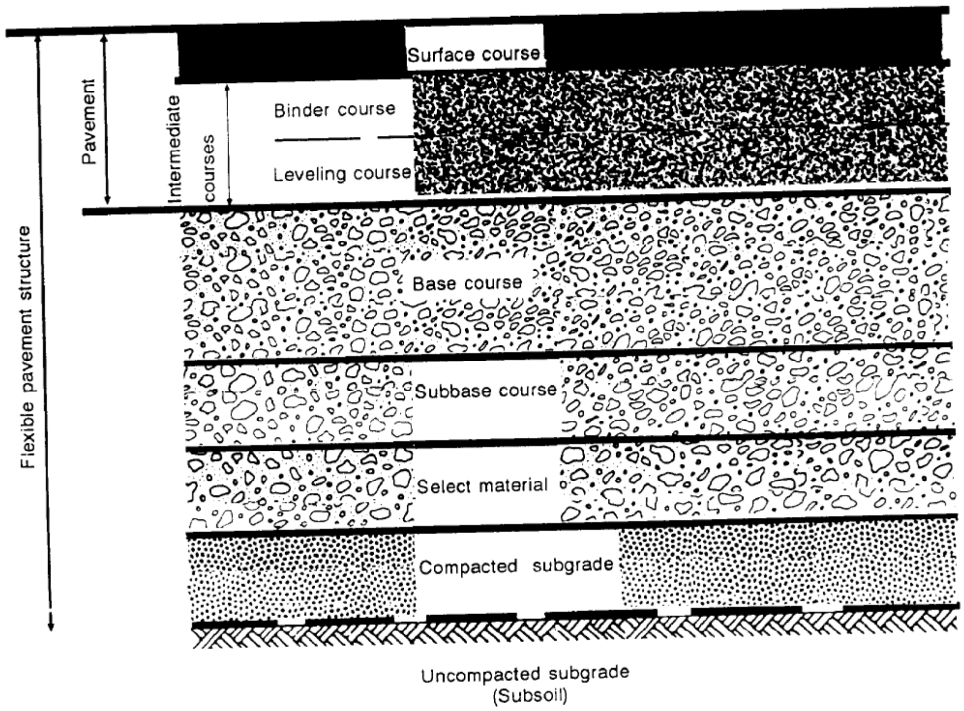



Figure 1 – Typical flexible-pavement section. (NOTE: not all layers and coats are present in every flexible-pavement structure. Intermediate courses may be placed in one or more lifts. Tack coats may be required between the intermediate courses and under the surface course. A prime coat may be required between the highest aggregate surface and the first layer of asphalt.)

Materials used in aggregate roads must meet the requirements listed below. Once a road class is designed, following design steps are needed for design of a roadway section.

A) Design Index (DI)

The design of roads will be based on a design index representing all traffic to use the road during its life. The DI is based on typical magnitudes and compositions of traffic reduced to equivalents in terms of repetitions of an 18,000-pound (8,180 kg), single-axel, duel-wheel load. For Class 1 roads, a DI of 6 shall be used. For Class 2 roads, a DI of 5 shall be used. This criteria assumes traffic containing more than 25% of two-axle trucks or more than 10% three, four or five axle trucks. The DI values also take into account up to 40, 20-30 tons track vehicles per day.

B) Check soils and construction aggregates.

1) Aggregate used for either the base, or sub-base shall meet the criteria set in Table 2 below. For base course, use the gradation meeting either the 1 ½ inch or 1 inch max columns per table 2.

Table 2 – Desirable gradation for crushed aggregate.

| Sieve Designations | Percent Passing Each Sieve (Square Openings) by Weight — Maximum Aggregate Size | | | |
|---|---|---|---|---|
| | 2 inch | 1 1/2 inch | 1 inch | 1-inch sand clay |
| 2 inch | 100 | | | |
| 1 1/2 inch | 70-100 | 100 | | |
| 1 inch | 55-85 | 75-100 | 100 | 100 |
| 3/4 inch | 50-80 | 60-90 | 70-100 | |
| 3/8 inch | 30-60 | 45-75 | 50-80 | |
| No. 4 | 20-50 | 30-60 | 35-65 | |
| No. 10 | 15-40 | 20-50 | 20-50 | 65-90 |
| No. 40 | 5-25 | 10-30 | 15-30 | 33-70 |
| No. 200 | 0-10 | 5-15 | 5-15 | 8-25 |

2) Check available material for road construction for maximum permissible values for sub-base and select materials listed in the table 3. The available materials are matched against each line listed in the table. The materials must meet the requirements listed in each column. If the material does not meet the requirements set forth in the column, then its dropped down to the next line and the process is continued. If the material does not meet any of the requirements set forth in the table, then it cannot be used as either sub-base or select material.

Table 3 – Maximum permissible values for sub-base and select materials.

| | | | Maximum Permissable Values for Gradation and Atterberg Limits | | | |
|---|---|---|---|---|---|---|
| | | | Gradation Requirements Percent Passing | | | |
| Material | Maximum Design CBR | Size In | No 10 Sieve | No 200 Sieve | Liquid Limit | Plasticity Index |
| Subbase | 50 | 2 | 50 | 15 | 25 | 5 |
| Subbase | 40 | 2 | 80 | 15 | 25 | 5 |
| Subbase | 30 | 2 | 100 | 15 | 25 | 5 |
| Select material | 20 | 3 | -- | -- | 35 | 12 |

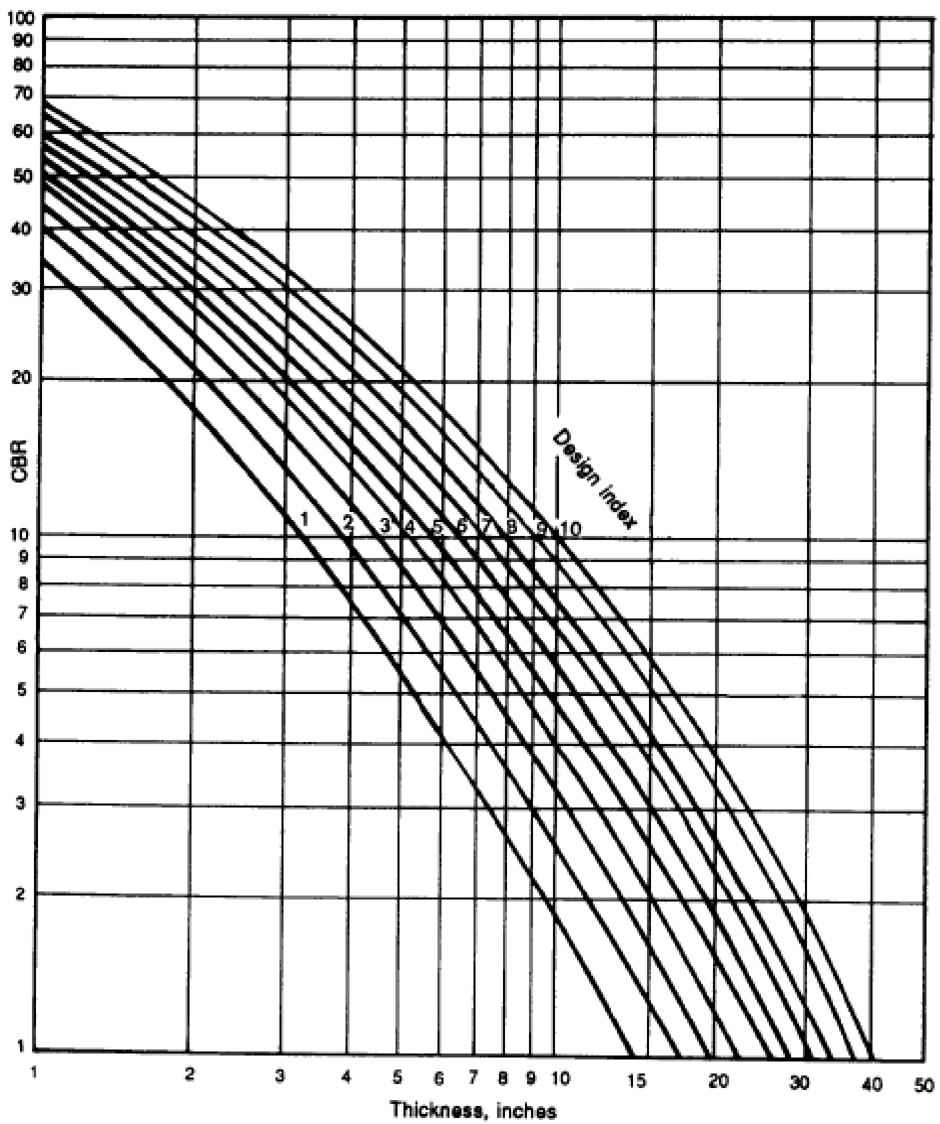
3) For base course, use gradation meeting either the 1 ½ inch or 1 inch max columns per table 2. The maximum CBR for base course shall not exceed CBR=80.

4) The sub-grade shall be scarified and compacted in place (SCIP). CBR values shall be determined of the sub-grade material. For design, use the lower of the two values; compacted CBR of existing material or a CBR value of 5. The minimum SCIP thickness shall be 6 inches (150mm) and compacted to 90-95% of the maximum dry density.

C) Determine the total road-structure thickness and cover requirement using Figure 2 below. Determine the minimum cover thickness, in inches, for each layer of the aggregate road Enter figure for each layer of soil or aggregate with the following information: DI and Design CBR for sub-grade, select and sub-base.

For a SCIP sub-grade CBR of 5 and a DI of 5, the overall thickness will be 10 inches (250 mm) over the sub-grade. For SCIP sub-grade CBR of 5 and a DI of 6, the overall thickness will be 12 inches (300 mm) over the sub-grade.

Figure 2 Design curves for aggregate-surface roads.



**4. Design Example – Aggregate Surfaced Road**

Design a pavement section given the following criteria:

1) ADT = 500
2) Two types of aggregates:
   a) Sample A: PI=4; LL=23; 12% Passing No. 200; 45% passing No. 5; Max aggregate is 1 inch and CBR is 35.
   b) Sample B: PI=10; LL=25; 15% Passing No. 200; 60% passing No. 5; Max aggregate is 1 inch and CBR is 28.
3) Natural CBR after compaction is 6
4) Base course aggregate meets gradation requirement per Table 2 with maximum aggregate being less than 1 inch.

<u>STEP 1</u>

With ADT= 500, the road class will be 1 per Table 1.

<u>STEP 2</u>

Based on road being class 1, the DI shall be 6.

<u>STEP 3</u>

Check what the available materials will be suitable for; is it suitable for sub-base or select course.

For Sample A; enter Table from top right corner and compare sample against Table 3 (table 3 is shown for comparison).

| | | Maximum Permissable Values for Gradation and Atterberg Limits | | | | |
|---|---|---|---|---|---|---|
| | | Gradation Requirements Percent Passing | | | | |
| Material | Maximum Design CBR | Size In | No 10 Sieve | No 200 Sieve | Liquid Limit | Plasticity Index |
| Subbase | 50 | 2 | 50 | 15 | 25 | 5 |
| Subbase | 40 | 2 | 80 | 15 | 25 | 5 |
| Subbase | 30 | 2 | 100 | 15 | 25 | 5 |
| Select material | 20 | 3 | -- | -- | 35 | 12 |

Start

PI=4; LL=23; 12% Passing No. 200; 45% passing No. 5; Max aggregate is 1 inch and CBR is 35

PI <5, move to next column.
LL<25, move to next column.
Less than 15% passing No.200 sieve, move to next column.
Less than 50% passing No. 10 sieve, move to next column.
Max aggregate size is less than 2, move to next two columns.
Actual sample CBR is 35. This is between 40 and 30 on the Maximum Design CBR column. Use Max Design CBR of 30, even though the actual is higher.
This material can be used for Sub-Base course

Repeat the same process for Sample B.

PI=10; LL=25; 15% Passing No. 200; 60% passing No. 5; Max aggregate is 1 inch and CBR is 28.

PI>5, so it meets the last line.
LL<35, and the actual CBR is 28.
The sample can be used for Select course with a Max Design CBR of 20.

STEP 4

Based on what is given in the example statement and from STEP 3 below is what we know so far:

SCIP Sub-Base = 5 (The actual CBR from laboratory test is 6, can only use 5 per Paragraph 2.B.4)
Sample B – can be used for Select Course with CBR = 20
Sample A – can be used for Sub-Base Course with CBR = 30
Base Course CBR = 80

Using figure 2 below is the list of different layers and their minimum thickness over it.

SCIP Sub-grade – 12 inches minimum cover above the layer.
Select – 4 inches minimum cover over the layer.
Sub-Base – 3 inches minimum cover over the layer (need to round up to 4 since layer thickness shall be 4 inch minimum).

The total thickness of all different layers combined above the SCIP Sub-grade needs to be 12 inches. It is up to the Engineer to determine what configuration to use at this point. Below are few scenarios.

Scenario 1: Base Course – 12 inches
SCIP Sub-Grade – 6 inches (this is the minimum required per Paragraph 3.B.4)

Scenario 2: Base Course – 4 inches
Sub-Base – 8 inches
SCIP Sub-Grade – 6 inches (this is the minimum required per Paragraph 3.B.4)

Scenario 3: Base Course – 4 inches
Sub-Base – 8 inches
SCIP Sub-Grade – 6 inches (this is the minimum required per Paragraph 3.B.4)

Scenario 4: Base Course – 4 inches
Select – 8 inches
SCIP Sub-Grade – 6 inches (this is the minimum required per Paragraph 3.B.4)

Scenario 5: Base Course – 4 inches
Sub-Base – 4 inches
Select – 4 inches
SCIP Sub-Grade – 6 inches (this is the minimum required per Paragraph 3.B.4)

Based on the above scenarios, the Contractor shall design the section based on materials that available and cost. Recommendation is to use either scenario 1 or 2.

**5. Flexible pavement design.**

If the contract calls for pavement to be placed over the aggregate surface road, the Contractor shall ensure the road is smooth with proper crown before placing pavement. Per Figure 1, a prime coat is required over the base course. The pavement section can consist of binder and leveling courses with a surface course over it. The minimum thickness of pavement shall be no less than 50 mm (2 inch) and shall meet the requirements of the contract documents.

## 6. Reference

FM 5-400-00-1 Planning and Design of Roads, Airfields, and Heliports in the Theater of Operations – Road Design; Department of the Army, August 1994.