Pavement Design for Roads, Streets, Walks, and Open Storage Areas

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Module 1: Introduction

Learning Objectives

By the end of this section, you will be able to:

- **Identify** the specific operational areas and loading conditions that mandate the use of rigid or composite pavements.
- **Evaluate** the five principal design variables required to determine the structural load-carrying capacity of a pavement system.
- **Distinguish** between the California Bearing Ratio (CBR) method for flexible pavements and the tensile stress-based procedure for rigid pavements.

Executive Summary: This module establishes the criteria for designing pavements, focusing on structural integrity through the management of five key variables: load, wheel configuration, traffic volume, soil strength, and flexural strength. While most pavement selections are driven by life-cycle cost analysis, specific high-stress or chemically sensitive areas—such as maintenance zones, tracked vehicle paths, and fueling pads—mandate rigid pavement construction.

Design Fundamentals

This course provides the technical criteria for the design of pavements for roads, streets, walks, and open storage areas specifically for military infrastructure.

Scope of Criteria

The engineering standards provided herein encompass:

- **Pavement Types:** Plain concrete, reinforced concrete, flexible pavements, and composite overlays.
- **Environmental Factors:** Specific design protocols for **seasonal frost** conditions.
- **Structural Components:** Requirements for subgrade, base courses, stabilized layers, and concrete joint detailing.
- **Compaction:** Standardized requirements to prevent consolidation under traffic loads.

References

For a complete list of technical references cited throughout this course, refer to **Appendix A**.

Selection of Pavement Type

While life-cycle cost analysis typically dictates the pavement type for most applications, **rigid pavements** (or composite pavements with a rigid overlay) are **mandatory** for the following high-demand areas:

- **Vehicle Maintenance and Parking:** Organizational vehicle parking, maintenance areas, and wash racks.

- **Specific Loading Conditions:** All pavements supporting tracked vehicles or vehicles equipped with nonpneumatic tires.
- **Storage Facilities:** Covered storage and open storage areas with nonpneumatic loadings exceeding **200 psi**.
- **Hazardous/Refueling Zones:** Vehicle fueling pads and areas subject to fuel spillage.

💡 **Design Tip:** For all areas not listed above, perform a comprehensive life-cycle cost analysis to determine the most economical pavement selection over the intended design life.

Basis of Design

Design Variables

The structural design of a pavement is primarily a function of its required **load-carrying capacity**. You must define the following five variables to determine the necessary thickness:

1. **Load:** Vehicle wheel or axle load.
2. **Geometry:** Configuration of vehicle wheels or tracks.
3. **Capacity:** Expected volume of traffic during the design life.
4. **Foundation:** Soil strength of the subgrade.
5. **Material Strength:** Modulus of rupture (flexural strength) specifically for concrete pavements.

Rigid Pavement Mechanics

The design for rigid systems focuses on **critical tensile stresses** produced within the slab.

- **Critical Loading:** Research indicates maximum tensile stresses occur when wheels are tangent to a **free or unsupported edge**.
- **Joint Efficiency:** Stresses are less severe at longitudinal or transverse joints because **load-transfer devices** distribute a portion of the load to adjacent slabs.
- **Secondary Stresses:** Design factors empirically account for cyclic stresses, including **thermal expansion/contraction** (restraint stresses) and **moisture/temperature gradients** (warping stresses).

Flexible Pavement Mechanics

Flexible pavement design utilizes the **California Bearing Ratio (CBR)** procedure.

- **Stress Distribution:** Each layer must be thick enough to ensure that stresses reaching the underlying layer do not cause **excessive shear deformation**.
- **Consolidation Control:** Adequate compaction is vital to prevent additional consolidation under traffic.

⚠️ **Safety Constraint:** You must use **ASTM D 1557** compaction effort procedures to ensure the pavement is designed against intolerable consolidation under traffic loads.

Computer Aided Design

Automated programs are available to assist in determining thickness and compaction requirements. These programs approximate the empirical data and curves found in this course.

Available Software

- **FRD 904:** Flexible Road Design program.
- **RRD 805:** Rigid Road Design program.

Checkpoint Quiz

1. **Which of the following scenarios mandates the use of a rigid pavement system regardless of life-cycle cost?**
   a) A pedestrian walkway with high foot traffic.
   b) A parking lot for standard pneumatic-tired staff vehicles.
   c) An open storage area with nonpneumatic loadings of 250 psi.
   d) A residential street within a base housing complex.

Answer: (c). Rigid pavements are mandatory for open storage areas where nonpneumatic loadings exceed 200 psi.

2. **According to the CBR design procedure for flexible pavements, what is the primary purpose of layer thickness?**
   a) To provide a smooth riding surface for high-speed traffic.
   b) To distribute traffic-induced stresses so they do not overstress underlying layers.
   c) To eliminate the need for subgrade compaction.
   d) To prevent thermal expansion of the asphalt binder.

Answer: (b). The CBR method requires each layer to be thick enough to reduce stresses to a level the underlying soil can support without shear deformation.

3. **In rigid pavement design, where do the maximum tensile stresses typically occur?**
   a) At the center of the slab.
   b) Tangent to a longitudinal joint with load-transfer devices.
   c) Tangent to a free or unsupported edge.
   d) At the bottom of the base course layer.

Answer: (c). Correlation between theory and traffic tests shows that stresses are most critical when the loading is tangent to an unsupported edge where no load transfer occurs.

Module 2: Preliminary Investigations

Learning Objectives

By the end of this section, you will be able to:

- **Evaluate** subgrade suitability based on soil classification, moisture-density relationships, and environmental susceptibility.
- **Determine** the required depth and frequency of subsurface explorations for both standard grades and borrow areas.
- **Identify** the critical data sources and mapping tools required for a comprehensive general survey of subgrade conditions.

Executive Summary: The performance and required thickness of a pavement structure are directly dictated by the strength and uniformity of the subgrade. Engineers must conduct thorough site investigations—including subsurface borings to a minimum of 6 feet—to classify soils under the Unified Soil Classification System (USCS) and assess risks such as frost action, pumping, and moisture-driven strength reduction.

Design Fundamentals

The subgrade serves as the foundational support for the entire pavement structure. To realize the maximum strength potential of a specific soil type, design and construction must prioritize **uniformity of support**.

⚠️ **Safety Constraint:** The importance of uniformity in soil and moisture conditions cannot be overemphasized, particularly in regions subject to **frost action**, where non-uniformity leads to differential heave and structural failure.

Investigations of Site

To accurately predict pavement performance, you must determine the following characteristics of the subgrade soils:

- **Classification:** Identify soil types using the **Unified Soil Classification System (USCS)** per ASTM D 2487.
- **Mechanical Properties:** Establish the moisture-density relationship and the degree of achievable compaction.
- **Risk Factors:** Assess expansion characteristics, susceptibility to **pumping**, and detrimental frost action.
- **Environmental Impact:** Evaluate how groundwater, surface infiltration, soil capillarity, topography, and rainfall will increase moisture content and reduce future subgrade strength.

