Concrete Floor Slabs on Grade Subjected to Heavy Loads

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Module 1: Introduction

Learning Objectives

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

- **Identify** the specific load thresholds that classify a project as a "heavy load" design.
- **Select** the appropriate design manual based on whether the facility is subjected to heavy, light, or vibratory loads.
- **Evaluate** the basic considerations of the working stress concept used in floor slab design.

Executive Summary: This manual provides the structural criteria for designing concrete floor slabs on grade subjected to heavy loads (forklift axle loads > 5 kips, stationary loads > 400 psf, or wall loads > 600 plf) using a working stress concept based on empirical pavement performance data.

Design Purpose

This manual prescribes the criteria for designing **concrete floor slabs on grade** in buildings specifically for **heavy loads**. This includes:

- **Moving loads** such as heavy vehicular traffic.
- **Stationary live loads** typical of warehouse storage.
- **Wall loads** from partitions and permanent structures.

Scope of Application

The manual covers theoretical concepts, practical applications, and the specific design procedures required for heavy-duty industrial and military environments.

⚠️ **Safety Constraint:** If your project falls outside the "heavy load" category, you must use alternate criteria:

- For **light-loaded areas** (e.g., office spaces), refer to TM 5-809-2/AFM 88-3, Chap. 2.
- For areas subjected to **vibratory loadings**, refer to TM 5-818-1/AFM 88-7, Chap. 1.

Technical Definitions

To ensure accurate application of the design index, engineers must distinguish between the following load classifications:

Term	Technical Definition
Slab on Grade	A concrete slab supported directly on foundation soil.
Light Loads	Forklift axle loads 5 kips or less AND stationary live loads less than 400 psf.
Heavy Loads	Any load exceeding: 5-kip forklift axle, 400 psf stationary live, or 600 plf wall load.
Design Load	Combined effects of stationary live, dead, wall, and moving live loads.
Dead Load	Permanent structure materials, fixed equipment, and permanent wall loads.

💡 **Design Tip:** Note that when calculating the **design load**, the dead loads of the floor slabs themselves are ignored.

Vibratory Loads are defined as dynamic and/or oscillatory loadings of significant magnitude. **Special Soils** refer to those with undesirable properties for construction, such as high compressibility or high swell potential.

Design Fundamentals

The design process follows a specific sequence of validation:

1. **Determine slab thickness** based on moving live loads.
2. **Check thickness adequacy** for stationary live loads.
3. **Determine thickness separately** for specific wall loads.

🧮 **Calculation Note:** The entire procedure is based on a **working stress concept**. Stresses induced by temperature gradients and other environmental effects are accounted for through the assignment of working stresses derived empirically from roadway and airfield pavement performance data.

Reinforcement Classifications

- **Nonreinforced Slab:** Contains minimal distributed steel (typically **Welded Wire Fabric**) only to limit crack width from shrinkage and temperature changes.
- **Reinforced Slab:** Contains steel reinforcement (WWF or deformed bars) to provide structural integrity to the slab resting on grade.

Checkpoint Quiz

1. **Which of the following load conditions would trigger the use of this "Heavy Load" manual instead of light-load criteria?**
   a. A stationary live load of 350 psf.
   b. A moving forklift axle load of 8 kips.
   c. A partition wall load of 500 plf.
   d. A dead load of 100 psf for fixed equipment.

Answer: (b). Heavy load criteria apply once a forklift axle exceeds 5 kips.

2. **How are stresses induced by temperature gradients handled in the design procedure?**
   a. By increasing the slab thickness by a flat 20% margin.
   b. By adding a specific amount of reinforcement steel.
   c. By the assignment of empirically established working stresses.
   d. They are ignored in the "heavy load" calculation.

Answer: (c). These stresses are taken into account through assigned working stresses developed from pavement performance data.

Module 2: Basis of Floor Slab on Grade Design

Learning Objectives

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

- **Identify** the primary variables that control tensile stresses induced by vehicular and stationary loads.
- **Evaluate** the impact of environmental factors, such as moisture and temperature gradients, on slab design safety factors.
- **Determine** the critical loading conditions for walls placed on concrete floor slabs on grade.

Executive Summary: Floor slab design is primarily governed by the management of tensile stresses from moving live loads and stationary loads, utilizing Westergaard's analysis and empirical safety factors to account for both mechanical and environmental stresses.

Stresses in Floor Slabs

The structural design of a concrete floor slab on grade is primarily controlled by the stresses caused by **moving live loads** and, in some instances, **stationary loads**.

Stresses resulting from vehicular loads are determined by several factors:

- **Slab Geometry**: Floor slab thickness.
- **Vehicle Characteristics**: Weight, weight distribution, and wheel or track configuration.
- **Material Properties**: Modulus of elasticity and Poisson's ratio of the concrete.
- **Foundation Support**: Modulus of subgrade reaction of the supporting material.

The **volume of traffic** anticipated over the design life is a critical factor for fatigue considerations.

Vehicle-Imposed Loads

Military vehicles are divided into three general classifications for design purposes:

1. **Forklift trucks**.
2. **Other pneumatic and solid-tired vehicles**.
3. **Tracked vehicles**.

Design requirements are established by relating a specific load to a **standard loading**.

⚠️ **Safety Constraint:** Environmental stresses—such as restraint stresses from thermal expansion/contraction and warping stresses from moisture/temperature gradients—are cyclic and will periodically add to moving live load stresses. These are accounted for via **safety factors** developed from full-scale accelerated traffic tests.

💡 **Design Tip:** Maximum tensile stresses typically occur when wheels are **tangent to a free edge**. Stresses at tied interior joints are less severe due to load transfer between slabs. However, designers must check for edge loading at doorways or free edges near walls.

Stationary Live Loads

The maximum allowable stationary live load is limited by both **positive bending moment** (under the load) and **negative bending moment** (at a distance from the load).

- **Positive Bending Moments**: Computed using **Westergaard's analysis** of elastically supported plates.
- **Negative Bending Moments**: A slab on an elastic subgrade deforms in a damped sine curve. Significant stress occurs at **critical aisle widths** where the deformation curves from parallel loading areas are in phase and additive.

🧮 **Calculation Note:** Westergaard's analysis is technically for plates on a **liquid foundation** (Winkler foundation). While often referred to as a "beam on elastic foundation" in textbooks, there is a distinct structural difference between liquid and elastic foundation behavior.

Wall Loads

Walls placed on new thickened slabs or existing slabs can weigh several thousand pounds per linear foot. Design calculations are based on the theory of a **beam on a liquid foundation**.

Three specific loading conditions must be considered:

1. Loads at the **center of the slab**.
2. Loads at a **joint**.
3. Loads at the **edge of the slab**.

Thickened slab widths and recommended transitions are developed based on these concentrated load theories.

Purchase this course to see the remainder of the technical materials.