

FM 5-436

Paving and Surfacing Operations

**Headquarters,
Department of the Army**

DISTRIBUTION RESTRICTION: Approved for public release; distribution is unlimited.

Paving and Surfacing Operations

Contents

	Page
PREFACE	x
INTRODUCTION	xi
Construction Principles	xi
Stage Construction	xi
Safe Construction	xi
Types of Pavements and Surfaces	xii
 PART ONE BITUMINOUS PAVEMENTS AND SURFACES	
 Chapter 1 BITUMINOUS MATERIALS	1-1
Section I - Bitumen	1-2
Types of Bitumen	1-2
Asphalt.....	1-2
Tar	1-2
Asphalt Cement	1-2
Asphalt Cutback	1-3
Asphalt Emulsion	1-3
Tar.....	1-4
Section II - Aggregate	1-5
Function	1-5
Types of Aggregate.....	1-5
Characteristics	1-6

Distribution Restriction: Approved for public release; distribution is unlimited.

*This publication supersedes Technical Manuals (TMs) 5-331D, 21 April 1969; 5-337, 21 February 1966; and 5-337-1, 29 March 1971.

	Page
Chapter 2	
BITUMINOUS DESIGN	2-1
Bitumen Selection.....	2-1
Asphalt Cement.....	2-1
Asphalt Cutback	2-1
Asphalt Emulsion	2-5
Tar.....	2-5
Aggregate Selection	2-5
Mix Gradation.....	2-5
Aggregate Blending.....	2-10
Example of Aggregate Blending.....	2-15
Reporting.....	2-18
Optimum Bitumen Content	2-18
Reporting Test Results.....	2-18
Evaluating Test Results	2-21
Job-Mix Formula	2-22
Chapter 3	
EQUIPMENT USED IN BITUMINOUS OPERATIONS	3-1
Section I - Production Equipment	3-1
Asphalt Plant	3-1
Batch and Continuous-Mix Plants	3-1
Cold-Feed Calibration	3-2
Dryer	3-3
Dust Collector.....	3-3
Screening	3-3
Percentage of Each Hot Bin.....	3-3
Mixing Aggregate and Asphalt	3-4
Drum Mixer	3-4
Cold-Feed Calibration	3-5
Dryer	3-5
Storage Silo	3-5
Travel Plant	3-5
Liquid Handling Equipment.....	3-5
Hauling Equipment	3-6
Support Equipment.....	3-6
Section II - Placement Equipment	3-6
Truck-Mounted Asphalt Distributor	3-6
Trailer-Mounted (Tankless) Asphalt Distributor	3-8
Asphalt Finisher.....	3-8
Compactors	3-10
Static Steel-Wheel Rollers	3-10
Vibratory Steel-Wheel Rollers	3-11
Rubber-Tired Rollers.....	3-11
Other Compaction Devices	3-12
Motor Grader	3-12
Hand Tools	3-12
Aggregate Spreaders	3-14
Surface-Treatment Combine	3-15

	Page
Chapter 4	
PRODUCTION AND LAYDOWN OF BITUMINOUS MATERIALS	4-1
Section I - Fundamentals	4-1
Construction.....	4-1
Handling and Stockpiling Aggregate.....	4-2
Traffic Problems.....	4-2
Section II - Prime and Tack Coats	4-3
Prime Coat.....	4-3
Base Preparation.....	4-3
Materials.....	4-3
Application.....	4-4
Curing Period.....	4-5
Protection.....	4-5
Tack Coat.....	4-5
Materials.....	4-5
Application.....	4-5
Curing Period.....	4-6
Protection.....	4-6
Section III - Surface Treatment	4-6
Single Surface Treatment.....	4-6
Aggregate.....	4-7
Bituminous Material.....	4-8
Rolling.....	4-9
Final Sweeping.....	4-9
Multiple Surface Treatment.....	4-9
Dust Palliative.....	4-10
Section IV - Penetration Macadam	4-10
Concept.....	4-10
Materials.....	4-11
Construction.....	4-11
Recondition the Base Course.....	4-13
Construct Edges on the Wearing Surface.....	4-13
Apply the Macadam Aggregate.....	4-13
Test the Course-Aggregate Thickness.....	4-14
Apply the First Layer of Bituminous Material.....	4-14
Protect the Area.....	4-15
Apply the Keystone.....	4-15
Broom and Roll the Aggregate.....	4-15
Apply the Second Layer of Bituminous Material.....	4-15
Apply the Choke Stone.....	4-15
Apply the Surface Treatment.....	4-16
Protect and Maintain the Pavement.....	4-16
Section V - Road-Mix Pavement	4-16
Concept.....	4-16
Bitumen.....	4-16
Aggregate.....	4-17
Mix Proportions.....	4-17
Construction.....	4-18

	Page
Prepare the Base	4-19
Place and Windrow the Aggregate.....	4-19
Mix the Materials	4-20
Blade Thickened Edges	4-21
Spread and Shape the Mix.....	4-21
Roll the Finished Surface	4-22
Shape the Edges.....	4-22
Take Samples	4-22
Treat the Surface	4-22
Section VI - Plant-Mix Pavement	4-22
Concept	4-22
Hot-Mix Bituminous Concrete.....	4-23
Cold-Laid Bituminous Plant Mix.....	4-25
Bituminous Materials	4-26
Laying a Hot M i x	4-26
Determining the Placement Temperature	4-27
Inspecting and Rejecting the Mix	4-27
Placing and Spreading the Mix	4-28
Computing the Depth	4-29
Adjusting the Screed	4-30
Raking the Mix	4-31
Adjusting the Mix.....	4-31
Rolling the Pavement.....	4-31
Density Tests.....	4-33
Selecting and Marking Samples.....	4-34
Removing Samples.....	4-35
Identifying Samples.....	4-35
Correcting Low Density	4-35
Longitudinal Joints.....	4-36
Construction	4-36
Alignment	4-38
Transverse Joints	4-38
Terminating a Lane	4-38
Rolling a Transverse Joint.....	4-39
Constructing Pavement Ends.....	4-39
Section VII - Special Mixes	4-40
Sand Asphalt and Tar	4-40
Sheet Asphalt	4-40
Stone-Filled Sheet Asphalt.....	4-40
Rock Asphalt	4-41
Chapter 5 FIELD MANUFACTURE OF ASPHALT CUTBACKS	5-1
Equipment and Production Rate.....	5-1
Safety	5-2
Procedures	5-3
Drums.....	5-4
Asphalt Cement.....	5-5
Temperature.....	5-5

	Page
Material Requirements	5-5
Chapter 6 MATERIAL ESTIMATES	6-1
Prime Coat	6-1
Tack Coat	6-2
Surface Treatment	6-2
Penetration Macadam	6-3
Road Mix	6-5
Plant Mix	6-5
Mileage Requirements	6-6
Chapter 7 MAINTAINING AND REPAIRING BITUMINOUS WEARING SURFACES	7-1
Principles.....	7-1
Materials.....	7-1
Inspections	7-2
Causes of Failure	7-2
Types of Failure	7-3
Potholes.....	7-3
Raveling.....	7-4
Cracking.....	7-4
Rutting and Shoving	7-4
Corrugation.....	7-4
Burned Areas.....	7-5
Bleeding.....	7-5
Settlements and Depressions.....	7-5
Patches	7-5
Premixed Patch	7-5
Penetration Patch	7-9
Skin Patch.....	7-10
Seal Coat.....	7-10
Craters	7-11
PART TWO CONCRETE PAVEMENTS	
Chapter 8 COMPONENTS OF CONCRETE	8-2
Types of Portland Cement	8-2
Water.....	8-3
Sea Water.....	8-3
Well Water (Sulfur)	8-3
Aggregate.....	8-3
Types	8-4
Characteristics	8-4
Gradations	8-4
Fineness Modulus.....	8-5
Blending.....	8-5
Admixtures	8-5
Air-Entraining Agents.....	8-6

	Page
Accelerators	8-6
Retardants.....	8-6
Plasticizers	8-6
Materials Handling and Storage	8-7
Aggregate.....	8-7
Cement.....	8-7
Chapter 9 CHARACTERISTICS OF CONCRETE	9-1
Plastic Concrete	9-1
Hardened Concrete	9-1
Air-Entrained Concrete	9-2
Production	9-2
Measurement of Air Content	9-3
Slump	9-3
Strength.....	9-3
Chapter 10 MIX DESIGN	10-1
Criteria	10-1
Water-to-Cement Ratio	10-1
Aggregate.....	10-3
Workability.....	10-3
Methods.....	10-3
Book Method.....	10-4
Trial-Batch Method.....	10-7
Chapter 11 CONCRETE EQUIPMENT	11-1
Concrete Mixer	11-1
Pneumatic Concrete Vibrator	11-1
Concrete Saw	11-2
Pin Puller	11-2
Water Heater	11-2
Concrete Bucket	11-2
Supporting Equipment	11-2
Central Mix Plant	11-3
M919 Concrete Mobile	11-3
Chapter 12 FORMS AND JOINTS	12-1
Section I - Forms	12-1
Procedures	12-2
Construction	12-2
Placement and Alignment.....	12-2
Handling	12-3
Section II - Joints.....	12-4
Types of Joints	12-4
Construction.....	12-4
Expansion	12-4
Contraction.....	12-5

	Page
Dowels	12-5
Installation of Joints.....	12-6
Longitudinal Construction Joints.....	12-7
Transverse Construction Joints	12-7
Expansion Joints.....	12-7
Concrete Placement	12-7
Final Positions	12-8
Joint Surfaces	12-8
Contraction Joints.....	12-8
Hand-Formed Joints	12-8
Sawed Joints	12-9
Sealing Joints.....	12-9
Chapter 13	
CONCRETE PAVING	13-1
Section I - Material Measurements and Truck Requirements	13-1
Cement.....	13-1
Water.....	13-1
Aggregate.....	13-2
Weight Measurement.....	13-2
Volume Measurement.....	13-2
Truck Requirements.....	13-2
Section II - Procedures	13-3
Sequence of Operations	13-3
Prepare the Subgrade.....	13-3
Mix the Concrete	13-4
Transport the Concrete	13-5
Prepare Expansion Joints	13-6
Place the Concrete.....	13-6
Vibrate the Concrete	13-6
Finish the Surface	13-7
Spreading	13-7
Hand Finishing and Floating.....	13-8
Straightedge Finishing	13-8
Burlap Drag Finishing	13-8
Prepare Contraction Joints.....	13-9
Finish the Edges	13-9
Cure the Concrete	13-9
Burlap or Cotton Mat.....	13-9
Waterproof-Paper Blanket or Impermeable Sheet.....	13-10
Membrane.....	13-10
Seal Joints and Cracks	13-11
Remove Forms.....	13-11
Test the Surface.....	13-11
Test the Strength.....	13-11
Section III - Cold- and Hot-Weather Techniques	13-11
Cold-Weather Construction.....	13-11
Frozen Subgrade.....	13-12
Effect of Temperature	13-13

	Page
Heating Equipment.....	13-16
Heat Preservation	13-16
Placing and Finishing.....	13-16
Protection After Finishing.....	13-16
Hot-Weather Construction	13-17
Section IV - Reinforced and Prestressed Concrete.....	13-18
Reinforced Concrete.....	13-18
Prestressed Concrete	13-20
Section V - Maintenance and Repair.....	13-21
Introduction.....	13-21
Types of Cement	13-21
Repair of Joints and Cracks	13-21
Repair of Areas.....	13-22
Repair of Breaks.....	13-23
Concrete Patches.....	13-23
Cement-Bound Macadam Patches	13-24
Bituminous Patches	13-24
Emergency Patches	13-24
Settlements.....	13-24

PART THREE EXPEDIENT OPERATIONS

Chapter 14	EXPEDIENT PAVEMENTS AND SURFACES	14-1
	Materials	14-2
	Special Considerations	14-2
	Roads	14-3
	Cross-Country Tracks.....	14-3
	Army Tracks	14-3
	Chespaling Mats.....	14-4
	Bamboo Mats	14-4
	Sommerfeld Track	14-6
	Construction.....	14-7
	Sommerfeld Sandwich	14-7
	Monkton Pack	14-7
	Wire Mesh	14-7
	Chain-Link Wire Mesh.....	14-9
	Chicken Wire and Expanded Metal Lath.....	14-9
	Heavy Expedient Roads and Pioneer Trails.....	14-9
	Mat Roads.....	14-10
	Plank Roads.....	14-11
	Plank-Tread Roads	14-12
	Log-Tread and Log-Plank Roads	14-12
	Corduroy Roads	14-12
	Pioneer Roads	14-16
	Mat Repair	14-17
	Surface Repair With Brick	14-17

	Page
Appendix A METRIC CONVERSIONS	A-1
Appendix B CHECKLIST FOR CONCRETE PAVING	B-1
GLOSSARY	Glossary-1
BIBLIOGRAPHY	Bibliography-1
INDEX	Index-1

Preface

Field Manual (FM) 5-436 provides essential information to military personnel who are engaged in or responsible for bituminous and concrete operations for roads and airfields. It contains information on construction materials and equipment and the mix design, production, placement, and repair of concrete and bituminous pavements.

Emphasis is primarily placed on the duties and responsibilities of engineer platoon sergeants, platoon leaders, company commanders, and staff personnel during bituminous and concrete operations. In addition, technical engineering specialists (military occupational specialty [MOS] 51T) are involved in quality control of bituminous and concrete operations.

FM 5-436 is a companion publication of FMs 5-410, 5-430-00-1, and 5-430-00-2. It completes the process of road and airfield construction.

Appendix A contains a metric conversion chart.

The proponent of this publication is HQ TRADOC. Forward comments and recommendations on Department of the Army (DA) Form 2028 to Commandant, United States Army Engineer School, ATTN: ATSE-TD-D, Fort Leonard Wood, Missouri 65473-6650.

Unless this publication states otherwise, masculine nouns and pronouns do not refer exclusively to men.

Introduction

CONSTRUCTION PRINCIPLES

The advent of devastating weapons and the increased mobility of modern warfare make it possible for combat sites to be located anywhere. Constructing roads and airfields must proceed even against tremendous difficulties. The durability of construction and other standards may require the modification of plans based on

- The immediate tactical or strategic situation.
- Urgent factors.
- The availability of manpower, materials, and equipment.
- Continuous enemy attack.

Understanding construction principles helps engineers attain the best construction possible using the materials available. Construction principles include making a sound plan for the route, clearing the right-of-way, evening out the roadbed, and making improvements to the surface.

STAGE CONSTRUCTION

Stage construction is the planned expansion (width or depth) of a road. Roads can be expanded (upgraded) using a minimum amount of time, manpower, and materials. Stage construction in depth is a vital consideration when planning combat-zone (CZ) roads. Flexible pavements lend themselves to this task. For example, an unsurfaced road was originally constructed in a CZ. As the combat area moves forward, surfacing the road with road-mix pavement increases the traffic capacity. When the road is part of the rear area, engineers pave it with a hot or cold plant mix if increased durability is necessary or they treat the surface if increased surface smoothness is needed. The road could then handle the high volume and heavy loads of rear-area traffic, assuming the base and subbase are adequate. Engineers must ensure that all layers are completely bonded.

As the load or amount of traffic increases, the road may need to be widened. During the planning stage of an original road construction, engineers should include widening allowances. For example, they plan for wide cuts and fills to allow for later road widening. (Most military widening operations are less than one lane width.)

SAFE CONSTRUCTION

Engineers must rigidly observe safety precautions and procedures during paving operations and when heating bitumens, especially if flammable materials are being used. They must also observe proper traffic maintenance procedures.

TYPES OF PAVEMENTS AND SURFACES

This manual addresses the following types of paving and surfacing operations:

- Bituminous pavements and surfaces (Part One).
- Concrete pavements (Part Two).
- Expedient operations (Part Three).

NOTE: The term *concrete* in this publication refers to portland-cement concrete unless specified otherwise.

Selecting the types of pavements and surfaces to construct is based on traffic conditions; the availability of equipment, manpower, and materials; time allotted; climatic and weather conditions; and expected subgrade deformations. Engineers are not limited to using the expedient methods discussed in this manual. Sound engineering principles and imagination often lead to improved expedient methods.

A pavement is the end result of an operation that contributes to the overall load-bearing capacity of a structure:

- Bituminous pavement is usually more than 1 inch thick, and concrete pavement is usually more than 6 inches thick.
- Flexible pavement gives or flexes under loads. Ideally, the load is distributed over a surface area that is proportional to the distance of the area from the surface.
- Rigid pavement, such as concrete, deflects slightly under a load and distributes it over a large area while bridging small weak spots in the base.

A surface retains and waterproofs a load-bearing course. Bituminous surface treatments and membranes are usually less than 1 inch thick and do not contribute to the load-bearing capacity of a base.