CE 451: Transp. Engg. II-Pavement Design and Railway Engineering

LOW COST ROAD; EQUIPMENTS; CONSTRUCTION OF EMBANKMENT, SUBGRADE, BASE, FLEXIBLE AND RIGID SURFACE; AND MAINTENANCE OF FLEXIBLE AND RIGID ROAD PAVEMENTS

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ROAD CONSTRUCTION

GENERAL CONSTRUCTION OPERATIONS
CONSTRUCTION EQUIPMENT - GENERAL REQUIREMENTS
MOBILIZATION
MAINTENANCE OF TRAFFIC
TEMPORARY WORK STRUCTURES
PREVENTION, CONTROL, AND ABATEMENT OF EROSION AND WATER POLLUTION
CONTRACTOR QUALITY CONTROL GENERAL REQUIREMENTS
CLEARING AND GRUBBING
EXCAVATION AND EMBANKMENT
FLOWABLE FILL
EXCAVATION FOR STRUCTURES AND PILES
GEOSYNTHETIC REINFORCEMENT
STABILIZING
PREPARED SOIL LAYER

FLOWABLE FILL
EXCAVATION FOR STRUCTURES AND PILES
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PREPARED SOIL LAYER
CRACKING AND RESEATING EXISTING CONCRETE PAVEMENT
ROCK BASE
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REWORKING LIMEROCK BASE
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SUPERPAVE ASPHALT BASE
RECLAIMED ASPHALT PAVEMENT BASE
OPTIONAL BASE COURSE
TURNOUT CONSTRUCTION (A widening in a highway to allow vehicles to pass or park)

ASPHALT TREATED PERMEABLE BASE
CEMENT TREATED PERMEABLE BASE
GRANULAR SUBBASE
PRIME AND TACK COATS FOR BASE COURSES
HOT BITUMINOUS MIXTURES - PLANT, METHODS, AND EQUIPMENT
MILLING OF EXISTING ASPHALT PAVEMENT
HOT BITUMINOUS MIXTURES - GENERAL CONSTRUCTION REQUIREMENTS
SUPERPAVE ASPHALT CONCRETE
ASPHALT RUBBER BINDER
ASPHALT CONCRETE FRICTION COURSES

VALUE ADDED ASPHALT PAVEMENT
MISCELLANEOUS ASPHALT PAVEMENT
ASPHALT RUBBER MEMBRANE INTERLAYER
PORTLAND CEMENT CONCRETE
PORTLAND CEMENT CONCRETE - CLASS I (NONSTRUCTURAL)
CEMENT CONCRETE PAVEMENT
GRINDING CONCRETE PAVEMENT
CONCRETE PAVEMENT SLAB REPLACEMENT
VALUE ADDED PORTLAND CEMENT CONCRETE PAVEMENT
BRIDGE APPROACH EXPANSION JOINTS

CONSTRUCTION EQUIPMENT - GENERAL REQUIREMENTS

Unless restricted to a specific type by the Contract Documents or the Engineer, the Contractor may perform the work using equipment, tools, machinery, etc., of his own choosing.

Remove from the job, alter, or repair equipment which is disapproved by he Engineer. Ensure that the number of units, the sizes, etc., of the equipment on hand are adequate to complete the work within the Contract Time.

Provide adequate equipment maintenance procedures to promote continuous satisfactory working condition and minimize noise pollution caused by construction equipment.

MOBILIZATION

Perform preparatory work and operations in mobilizing for the movement of personnel, equipment, supplies, and incidentals to the project site and for the establishment of temporary offices, buildings, safety equipment and first aid supplies, and sanitary and other facilities.

MAINTENANCE OF TRAFFIC

Maintain traffic within the limits of the project for the duration of the construction period, including any temporary suspensions of the work.

Construct and maintain detours.

Provide facilities for access to residences, businesses, etc., along the project.

Furnish, install and maintain traffic control and safety devices during construction. Furnish and install work zone pavement markings for maintenance of traffic in construction areas

Do not obstruct or create a hazard to any traffic during the performance of the work, and repair any damage to existing pavement open to traffic

Alternative Traffic Control Plan

standard for traffic control for highway construction, maintenance, and utility operations

Maintain all lanes that are being used for he maintenance of traffic, including those on detours and temporary facilities, under all weather

Keep the lanes reasonably free of dust, potholes and rutting
Keep enough traffic lanes to avoid congestion

Provide and maintain adequate accommodations for intersecting and crossing traffic

Do not block or unduly restrict any road or street crossing

Detour

Construct and maintain detour facilities wherever it becomes necessary

Plan, construct, and maintain detours for the safe passage of traffic in all conditions of weather.

Remove detours when they are no longer needed

Ensure that each residence and or business has safe, stable, and reasonable access

Install and maintain adequate traffic control

Devices, warning devices and barriers to protect the traveling public and workers, and to safeguard the work area.

Keep traffic control devices, warning devices, safety devices and barriers in the

Correct position, properly directed, clearly visible and clean, at all times. Immediately repair, replace or clean damaged, defaced or dirty devices or barriers.

Tools & Devices

- Work Zone Signs
- High Intensity Flashing Lights
- Warning/Channelizing Devices
- Reflective Collars for Traffic Cones
- Barrier Wall (Temporary)
- Guardrail
- Advance Warning Arrow Panel
- Portable Changeable (Variable) Message Sign (PCMS)
- Work Zone Pavement Marking.

PREVENTION, CONTROL, AND ABATEMENT OF EROSION AND WATER POLLUTION

Incorporation of Erosion Control Features:

Incorporate permanent erosion control features into the project at the earliest practical time.

Schedule operations such that the area of unprotected erodible earth exposed at any one time is not larger than the minimum area necessary for efficient construction Operations, and the duration of exposure of uncompleted construction to the elements is as short as practicable.

Details for Temporary Erosion Control Features:

temporary grassing / temporary mulching,
sandbagging,
slope drains,
sediment basins & sediment checks,
berms,
baled hay or straw,
floating & staked turbidity barrier,
and silt fence.

CONTRACTOR QUALITY CONTROL GENERAL REQUIREMENTS

- ❑ Personel
- ❑Equipment
- ❑Track record
- ❑Standard certificate
- ❑Material and testing std certificate

CLEARING AND GRUBBING

❖Clear and grub within the areas of the roadway right-of-way and of borrow pits, sandclay base material pits, lateral ditches, and any other areas shown in the plans to be cleared and grubbed.

❖Remove and dispose of all trees, stumps, roots and other such protruding objects, buildings, structures, appurtenances, existing flexible asphalt pavement, and other facilities necessary to prepare the area for the proposed construction.

❖ Remove and dispose of all product and debris not required to be salvaged or not required to complete the construction.

❖Plug any water wells that are encountered within the right-of-way and that are to be abandoned.

❖Level the terrain outside the limits of construction for purposes of facilitating maintenance and other post-construction operations

❖Trim trees and shrubs within the project right-of-way that are identified in the Contract Documents.

❖Plow the surface to a depth of at least 6 inches, and remove all roots thereby exposed to a depth of at least 12 inches.

EXCAVATION AND EMBANKMENT

Regular Excavation:

Roadway Excavation: Roadway Excavation consists of the excavation and the utilization or disposal of all materials necessary for the construction of the roadway, ditches, channel changes, etc., except as may be specifically shown to be paid for separately and that portion of the lateral ditches within the limits of the roadway right-of-way as shown in the plans.

Borrow Excavation: Borrow Excavation consists of the excavation and utilization of material from authorized borrow pits, including only material that is suitable for the construction of roadway embankments or of other embankments covered by the Contract.

Subsoil Excavation: Subsoil Excavation consists of the excavation and disposal of muck, clay, rock, or any other material that is unsuitable in its original position and that is excavated below the finished grading template.

Lateral Ditch Excavation: Lateral Ditch Excavation consists of all excavation of inlet and outlet ditches to structures and roadway, changes in channels of streams, and ditches parallel to the roadway right-of-way.

Channel Excavation: Channel Excavation consists of the excavation and satisfactory disposal of all materials from the limits of the channel as shown in the plans.

Another Classification

Rock Excav..

Common excav

Unsuitable excav

Borrow Excav..

Materials for Embankment.

Construct embankments of acceptable material including broken portland cement concrete pavement and portland cement concrete rubble, but containing no muck, stumps, roots, brush, vegetable matter, rubbish, reinforcement bar or other material that does not compact into a suitable and enduring roadbed.

Remove and waste material designated as undesirable.

Complete the embankment using maximum particle sizes (in any dimension) as follows:

In top 12 inches: 3 1/2 inches (in any dimension).

12 to 24 inches: 6 inches (in any dimension).

In the depth below 24 inches: not to exceed 12 inches (in any dimension) or the compacted thickness of the layer being placed, whichever is less.

Spread all material so that the larger particles are separated from each other to minimize voids between them during compaction.

Embankment Construction.

Construct embankments in sections of not less than 300 feet in length or for the full length of the embankment.

A LOT is defined as a single lift of finished embankment not to exceed 500 feet.

Isolated compaction operations will be considered as separate LOTs. For multiple phase construction, a LOT shall not extend beyond the limits of the phase.

Dry Fill Construction Method:

Restrict the compacted thickness of the ***last*** embankment lift to 6 inches maximum.

Materials with up to 15% fines: Construct the embankment in successive layers with lifts up to a maximum compacted thickness of 12 inches.

Materials with greater than 15% fines: Construct the embankment in successive layers with lifts up to a maximum compacted thickness of 6 inches.

Alternately, for A-1, Plastic material and A-2-4 Materials with greater than 15% fines, construct embankments using thick lift construction in successive layers of not more than 12 inches compacted thickness,

Hydraulic Method:

Method of Placing: When the hydraulic method is used, as far as practicable, place all dredged material in its final position in the embankment by such method. Place and compact any dredged material that is rehandled, or moved and placed in its final position by any other method.

When placing fill on submerged land, construct dikes prior to beginning of dredging, and maintain the dikes throughout the dredging operation.

Protection of Openings in Embankment: Leave openings in the embankments at the bridge sites. Remove any material which invades these openings or existing channels without additional compensation to provide the same depth of channel as existed before the construction of the embankment. Do not excavate or dredge any material within 200 feet of the toe of the proposed embankment.

Compaction Requirements.

Moisture Content: Compact the materials at a moisture content such that the specified density can be attained. If necessary to attain the specified density, add water to the material, or lower the moisture content by manipulating the material or allowing it to dry, as is appropriate.

Compaction of Embankments:

Uniformly compact each layer, using equipment that will achieve the required density, and as compaction operations progress, shape and manipulate each layer as necessary to ensure uniform density throughout the embankment.

Quality Control Tests (By Contractor)

Standard Proctor Maximum Density Determination:
Determine the Quality Control standard Proctor maximum density and optimum moisture content by sampling and testing the material in accordance with the specified test method

Density Testing Requirements: Ensure compliance to the requirements by Nuclear Density testing. Determine the in-place moisture content for each density test.

Test Name	Quality Control	Verification
Standard Proctor Maximum Density	One per soil type	One per soil type
Density	One per LOT	One per four LOTs and for wet conditions, the first lift not affected by water
Soil Classification	One per Standard Proctor Maximum Density	One per Standard Proctor Maximum Density

Verification Comparison Criteria and Resolution Procedures:

Standard Proctor Maximum Density Determination: The Engineer will verify the Quality Control results if the results compare within 4.5 lb/ft3 of the Verification test result. Otherwise, the Engineer will take one additional sample of material from the soil type in question.

The Engineer will compare the Resolution Test results with the Quality Control test results. If all Resolution Test results are within 4.5 lb/ft3 of the corresponding Quality Control test results, the Engineer will use the Quality Control test results for material acceptance purposes for each LOT with that soil type.

If the Resolution Test result is not within 4.5 lb/ft3 of the Contractor's Quality Control test, the Verification Test result will be used for material acceptance purposes.

When a Verification or Independent Verification density test fails the Acceptance Criteria, retest the site within a 5 feet radius

Construction QUALITY

Construction Tolerances: Shape the surface of the earthwork to conform to the lines, grades, and cross-sections shown in the plans. In final shaping of the surface of earthwork, maintain a tolerance of 0.3 foot above or below the plan cross-section with the following exceptions:

1. Shape the surface of shoulders to within 0.1 foot of the plan cross-section.

2. Shape the earthwork to match adjacent pavement, curb, sidewalk, structures, etc.

3. Shape the bottom of ditches so that the ditch impounds no water.

4. When the work does not include construction of base or pavement, shape the entire roadbed (shoulder point to shoulder point) to within 0.1 foot above or below the plan cross-section.

Ensure that the shoulder lines do not vary horizontally more than 0.3 foot from the true lines shown in the plans.

Base Construction

GRADED AGGREGATE BASE

Base course composed of graded aggregate.

Thickness and CBR and other characteristic provided by Pavement design

Hunt material/gradation to meet those criteria

Typical Gradation

Sieve Size	Percent by Weight Passing
2 inch	100
1 1/2 inch	95 to 100
3/4 inch	65 to 90
3/8 inch	45 to 75
No. 4	35 to 60
No. 10	25 to 45
No. 50	5 to 25
No. 200	0 to 10

Transporting Aggregate.

Transport the rock to its point of use, over rock previously placed, if practicable, and dump it on the end of the preceding spread. Hauling and dumping on the subgrade will be permitted only when, in the Engineer's opinion, these operations will not be detrimental to the subgrade.

Spreading Aggregate.

Spread the rock uniformly. Remove all segregated areas of fine or coarse rock and replace them with properly graded rock.

When the specified compacted thickness of the base is greater than 6 inches, construct the base in multiple courses of equal thickness. Individual courses shall not be less than 3 inches. The thickness of the first course may be increased to bear the weight of the construction equipment without disturbing the subgrade.

If, through field tests, the Contractor can demonstrate that the compaction equipment can achieve density for the full depth of a thicker lift, and if approved by the Engineer, the base may be constructed in successive courses of not more than 8 inches compacted thickness.

Compacting and Finishing Base.

Thickness Requirements: Within the entire limits of the length and width of the finished base, meet the specified plan thickness in accordance with the requirements

Quality control: Density and MC requirement similar to Subgrade Construction

Frequency: Conduct QC sampling and testing at a minimum frequency listed in the table below.

Test Name	Quality Control	Verification
Modified Proctor Maximum Density	One per eight consecutive LOTs	One per 16 consecutive LOTs
Density	One per LOT	One per four LOTs
Roadway Surface	Ten per LOT	Three per LOT
Shoulder/widening* Surface	Five per LOT	One per LOT
Roadway Thickness	Three per LOT	Three per four LOTs
Shoulder/widening* Thickness	Three per two consecutive LOTs	Three per eight consecutive LOTs
* Note = For widening less than or equal to 5ft.		

If Happy with construction Do Priming i.e. Application of liquid bitu material to help bonding, to prevent Capillary rise

PRIME AND TACK COATS FOR BASE COURSES

PRIME COAT
Applied to previously untreated base or wearing surface

TACK COATS
Single application of bituminous material to existing ACC/PCC surface/base

Materials
Cut-back Asphalt Grade
Emulsified Asphalt

***Cover Material for Prime Coat*: sand or screenings for the cover material.**
Provide a pressure distributor

Application of Tack Coat:
Apply the tack coat with a pressure distributor except that on small jobs, if approved by the Engineer, apply it by other mechanical devices or by hand methods. Heat the bituminous material to a suitable temperature as designated by the Engineer, and apply it in a thin, uniform layer.

Keep the tack coat surface free from traffic until the subsequent layer of bituminous hot mix has been laid.

HOT BITUMINOUS MIXTURES - GENERAL CONSTRUCTION REQUIREMENTS

Constructing plant-mixed hot bituminous pavements and bases.

Minimum Quality Control Plan

***Stockpiles*: Assure materials are placed in the correct stockpile; assure good stockpiling techniques; inspect stockpiles for separation, contamination, segregation, etc.; properly identify and label each stockpile.**

***Incoming Aggregate*: Obtain gradations and bulk specific gravity (Gsb) values from aggregate supplier for reference; determine the gradation of all component materials; routinely compare gradations and Gsb values to mix design.**

Dryer: Observe pyrometer for aggregate temperature control; observe efficiency of the burner.

***For Batch Plants*, determine percent used and weight to be pulled from each bin to assure compliance with Mix Design, check mixing time, and check operations of weigh bucket and scales.**

***For Drum Mixer Plants*, determine aggregate moisture content, and calibrate the weigh bridge on the charging conveyor.**

Testing frequencies in the Quality Control Plan:

Asphalt Plant

1. Hot Mix Asphalt: Determine the asphalt binder content; mix gradation and volumetric properties at a minimum frequency of one per day. In the event that the daily production exceeds 1,000 tons, perform these tests a minimum of two times per day. Quality Control tests used in the acceptance decision may be used to fulfill this requirement. Verify modifier addition.

2. *Aggregate*: One sample per 1,000 tons of incoming material as it is stockpiled for gradation.

3. Mix temperature for the first five loads and every fifth load thereafter.

4. Aggregate moisture content from stockpiles or combined cold feed aggregate - one per day.

5. Other tests (as determined necessary by the Contractor) for process control.

Preparation of Asphalt Cement.

Deliver the asphalt cement to the asphalt plant at a temperature not to exceed 370ºF,

Maintain the asphalt cement in storage within a range of 230 to 370ºF in advance of mixing operations.

Preparation of Aggregates:

***Stockpiles*: Place each aggregate component in an individual stockpile, and separate each from the adjacent stockpiles,**

***Prevention of Segregation*: Form and maintain stockpiles in a manner that will prevent segregation.**

Blending of Aggregates:

Preparation of the Mixture.

Batch Mixing:

Aggregates: Once the dried aggregates and mineral filler (if required) are prepared in the manner previously described and combined in batches to meet the verified mix design by weighing each separate bin size, convey them to the empty mixer.

Asphalt Binder: Introduce the accurately measured hot asphalt binder into the mixer simultaneously with, or after, the hot aggregates. Continue mixing until the mixture is thoroughly uniform with all particles fully coated.

Continuous Mixing:

Introduce the dried aggregates and mineral filler (if required), prepared as specified and proportioned to meet the verified mix design, into the mixer in synchronization with the accurate feeding of the hot asphalt cement. Mix sufficiently to produce a thoroughly and uniformly coated mixture.

Maximum Period of Storage:
Allow the maximum time that any mix may be kept in a hot storage or surge bin to be 72 hours.

Transportation of the Mixture:

Transport the mixture in tight vehicles previously cleaned of all foreign material. After cleaning, thinly coat the inside surface of the truck bodies with soapy water or an asphalt release agent as needed to prevent the mixture from adhering to the beds.

Preparation of Application Surfaces

Cleaning:

Prior to the laying of the mixture, clean the surface of the base or pavement to be covered of all loose and deleterious material by the use of power brooms or blowers, supplemented by hand brooming where necessary.

Patching and Leveling Courses:

Where an asphalt mix is to be placed on an existing pavement or old base which is irregular, and wherever the plans indicate, bring the existing surface to proper grade and cross-section by the application of patching or leveling courses.

Application Over Surface Treatment:

Where an asphalt mix is to be placed over a newly constructed surface treatment, sweep and dispose of all loose material from the paving area.

Coating Surfaces of Contacting Structures:

Paint all structures which will be in actual contact with the asphalt mixture, with the exception of the vertical faces of existing pavements and curbs or curb and gutter, with a uniform coating of asphalt cement to provide a closely bonded, watertight joint.

Tack Coat Required:

Apply a tack coat, as specified , on existing pavement structures that are to be overlaid with an asphalt mix and between successive layers of all asphalt mixes.

Placing Mixture.

Spreading and Finishing: Upon arrival, dump the mixture in the approved mechanical spreader, and immediately spread and strike-off the mixture to the full width required, and to such loose depth for each course that, when the work is completed, the required weight of mixture per square yard, or the specified thickness, is secured.

Thickness of Layers:

Laying Width:

Correcting Defects: Before starting any rolling, check the surface; correct any irregularities; remove all drippings, fat sandy accumulations from the screed, and fat spots from any source; and replace them with satisfactory material.

Compacting Mixture.

When density testing for acceptance is required, select equipment, sequence, and coverage of rolling to meet the specified density requirement. The coverage is the number of times the roller passes over a given area of pavement. Regardless of the rolling procedure used, complete the final rolling before the surface temperature of the pavement drops to the extent that effective compaction may not be achieved or the rollers begin to damage the pavement.

Standard Rolling Procedure:

Meet the following equipment, sequence, and coverage requirements:

1. Seal Rolling: Provide two coverages with a tandem steel wheeled roller (either vibratory or static), weighing 5 to 12 tons, following as close behind the spreader as possible without pick-up, undue displacement, or blistering of the material. Use vibratory rollers in the static mode for layers of 1 inch or less in thickness.

2. Intermediate rolling: Provide five coverages with a self propelled pneumatic-tired roller, following as close behind the seal rolling operation as the mix will permit.

3. Final rolling: Provide one coverage with a tandem steel-wheeled roller (static mode only), weighing 5 to 12 tons, after completing the seal rolling and intermediate rolling, but before the surface pavement temperature drops to the extent that effective compaction may not be achieved or the rollers begin to damage the pavement.

Surface Requirements.

Texture of the Finished Surface of Paving Layers: Produce a finished surface of uniform texture and compaction with no pulled, torn, raveled, crushed or loosened portions and free of segregation, bleeding, flushing, sand streaks, sand spots, or ripples.

Cross Slope: Construct a pavement surface with cross slopes in compliance with the requirements of the Contract Documents.

Pavement Smoothness: Construct a smooth pavement meeting the requirements of this Specification.

Protection of Finished Surface.

To prevent rutting or other distortion, protect sections of newly finished dense graded friction course and the last structural layer prior to the friction course from traffic until the surface temperature has cooled below 160ºF.

PLANNING AND EXECUTION OF CONSTRUCTION

TENTATIVE STEPS:

- **Detailed analysis of amount of works of different types**
- **Plans are examined and the location, extent, and conditions affecting the execution of each steps of work are determined**
- **Detailed analysis of the equipment, labor and material requirement for each phase of project**
- **Equipment production rate, quantity of work and number of units needed**
- **Combine all these to produce a schedule of construction operation**

Gantt Chart

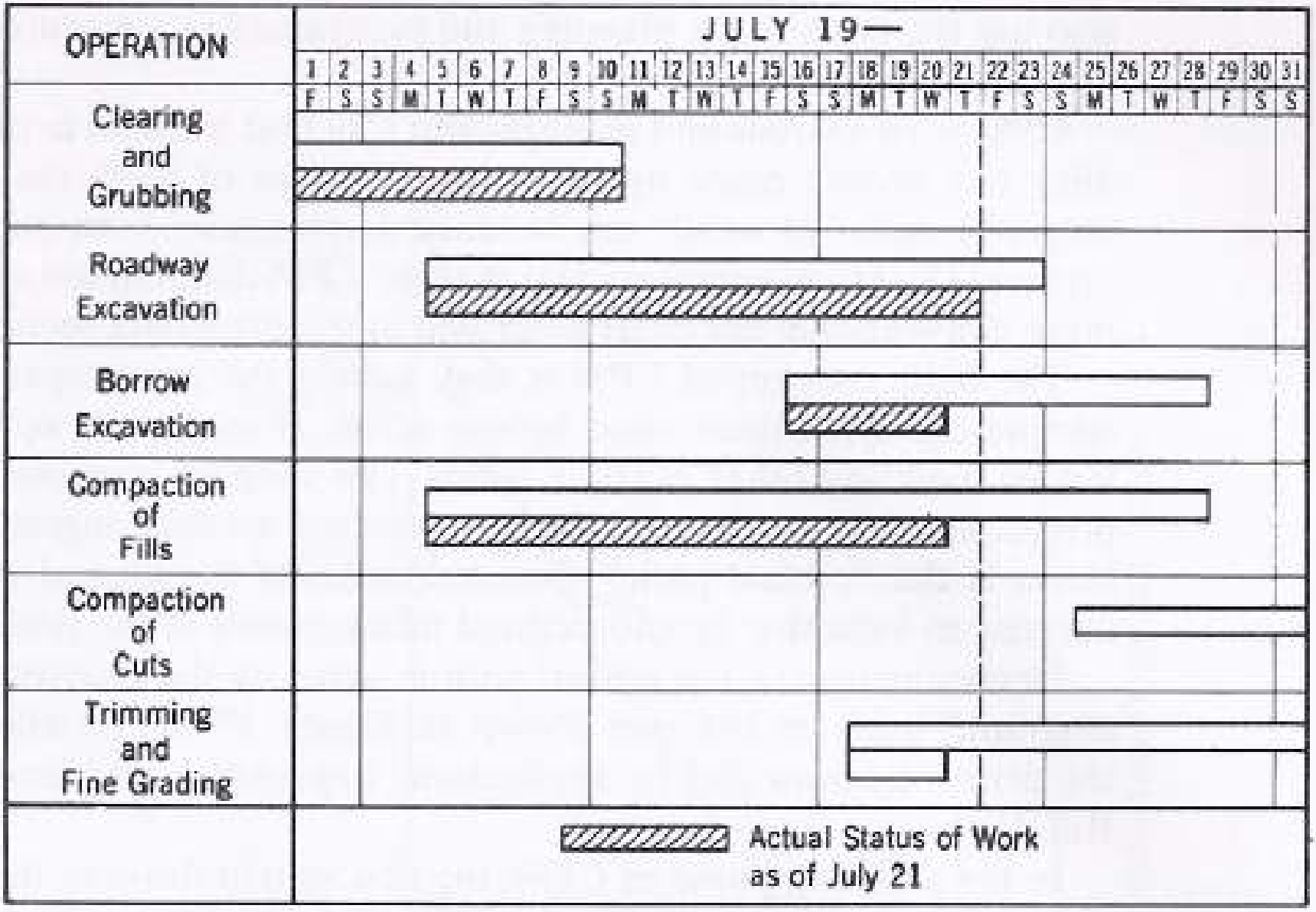

FIGURE 17-9 Schedule of construction operations.

CPM (CRITICAL PATH METHOD)

Single estimate of activity time
Deterministic activity times

PERT (PROGRAM EVALUATION AND REVIEW TECHNIQUE)

Multiple time estimates
Probabilistic activity times

Overtime CPM and PERT became one technique

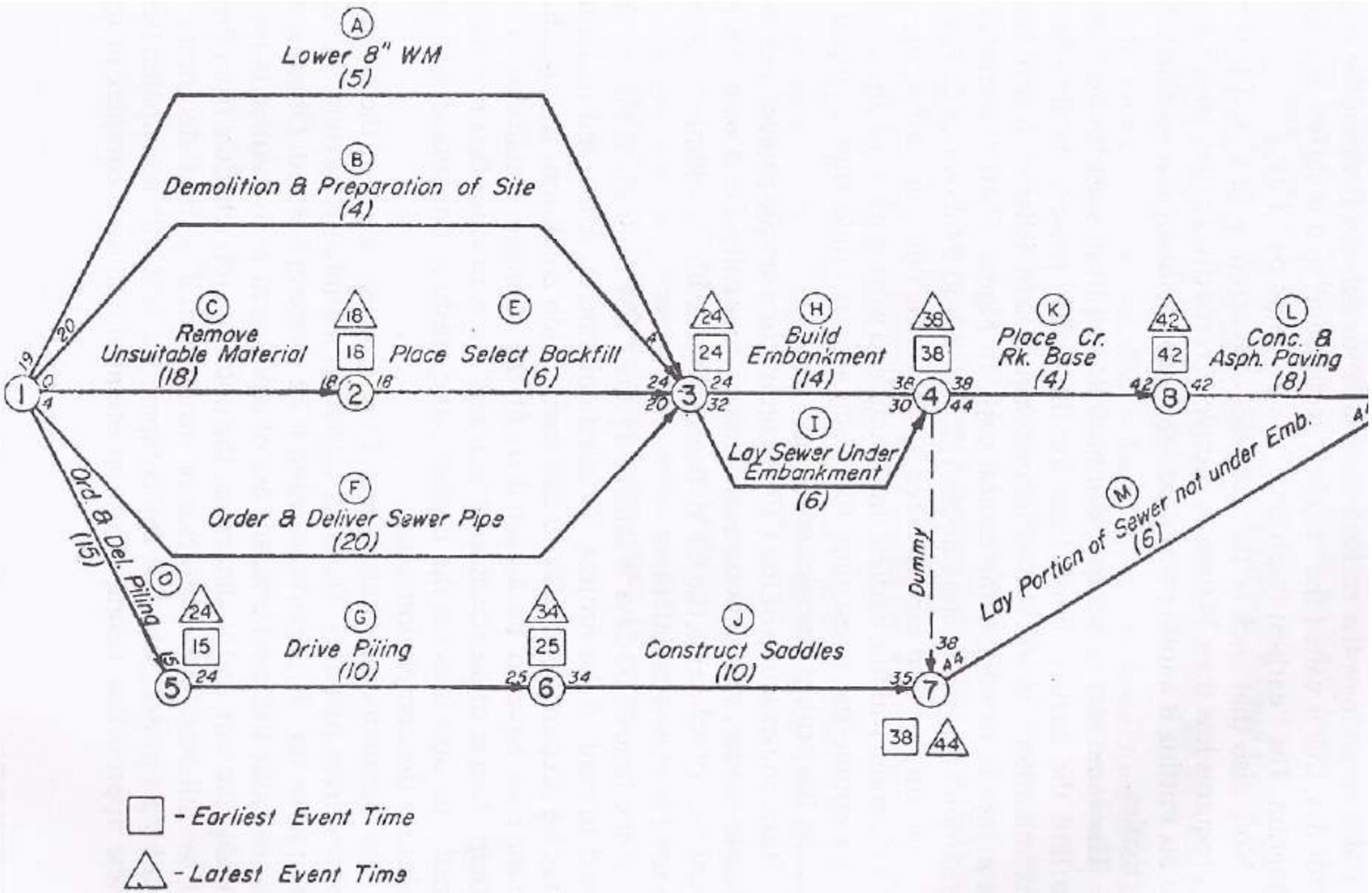

FIGURE 17-10 Typical critical path diagram for a simple highway project. (Courtesy Douglas L. Jonas.)

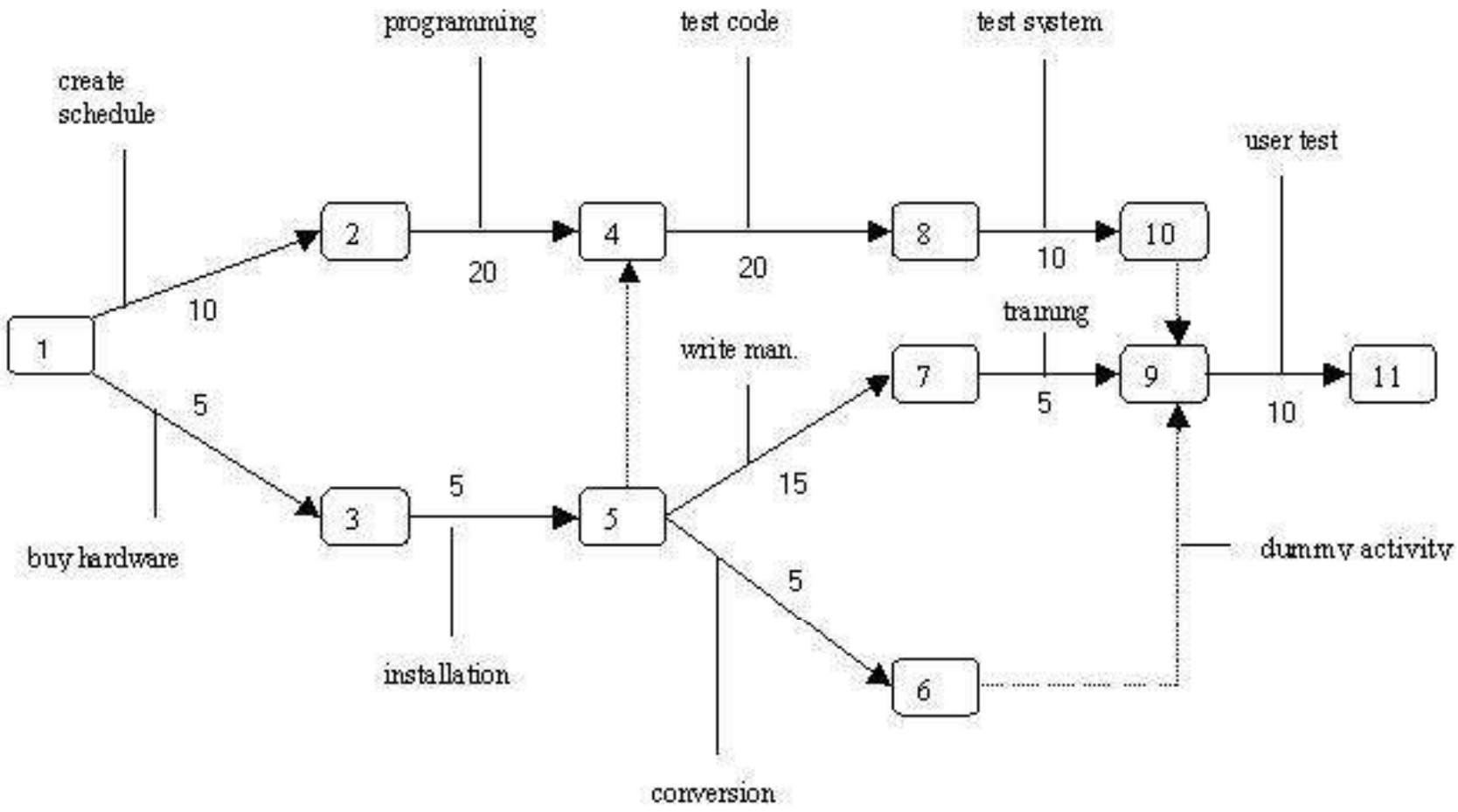

Fig. 1:
PERT Chart

* Numbered rectangles are nodes and represent events or milestones.
* Directional arrows represent dependent tasks that must be completed sequentially.
* Diverging arrow directions (e.g. 1-2 & 1-3) indicate possibly concurrent tasks
* Dotted lines indicate dependent tasks that do not require resources.

A PERT chart is a project management tool used to schedule, organize, and coordinate tasks within a project. PERT stands for *Program Evaluation Review Technique*, A PERT chart presents a graphic illustration of a project as a network diagram consisting of numbered *nodes* (either circles or rectangles) representing events, or milestones in the project linked by labelled *vectors* (directional lines) representing tasks in the project. The direction of the arrows on the lines indicates the sequence of tasks.

The PERT chart is sometimes preferred over the Gantt chart, another popular project management charting method, because it clearly illustrates task dependencies. On the other hand, the PERT chart can be much more difficult to interpret, especially on complex projects. Frequently, project managers use both techniques.

CONSTRUCTION OF CONCRETE PAVEMENTS

STEPS:

1. **Preparation and preliminary finishing of subgrade**
2. **Placing of forms**
3. **Final finishing of the subgrade**
4. **Installation of joints**
5. **Batching of aggregate and cements**
6. **Mixing and placing concrete**
7. **Placing and finishing concrete**
8. **Slipform paving**
9. **Curing**

FIGURE 20-12 Cutting of trench to exact line and grade, prior to placing of forms. (Courtesy Portland Cement Association.)

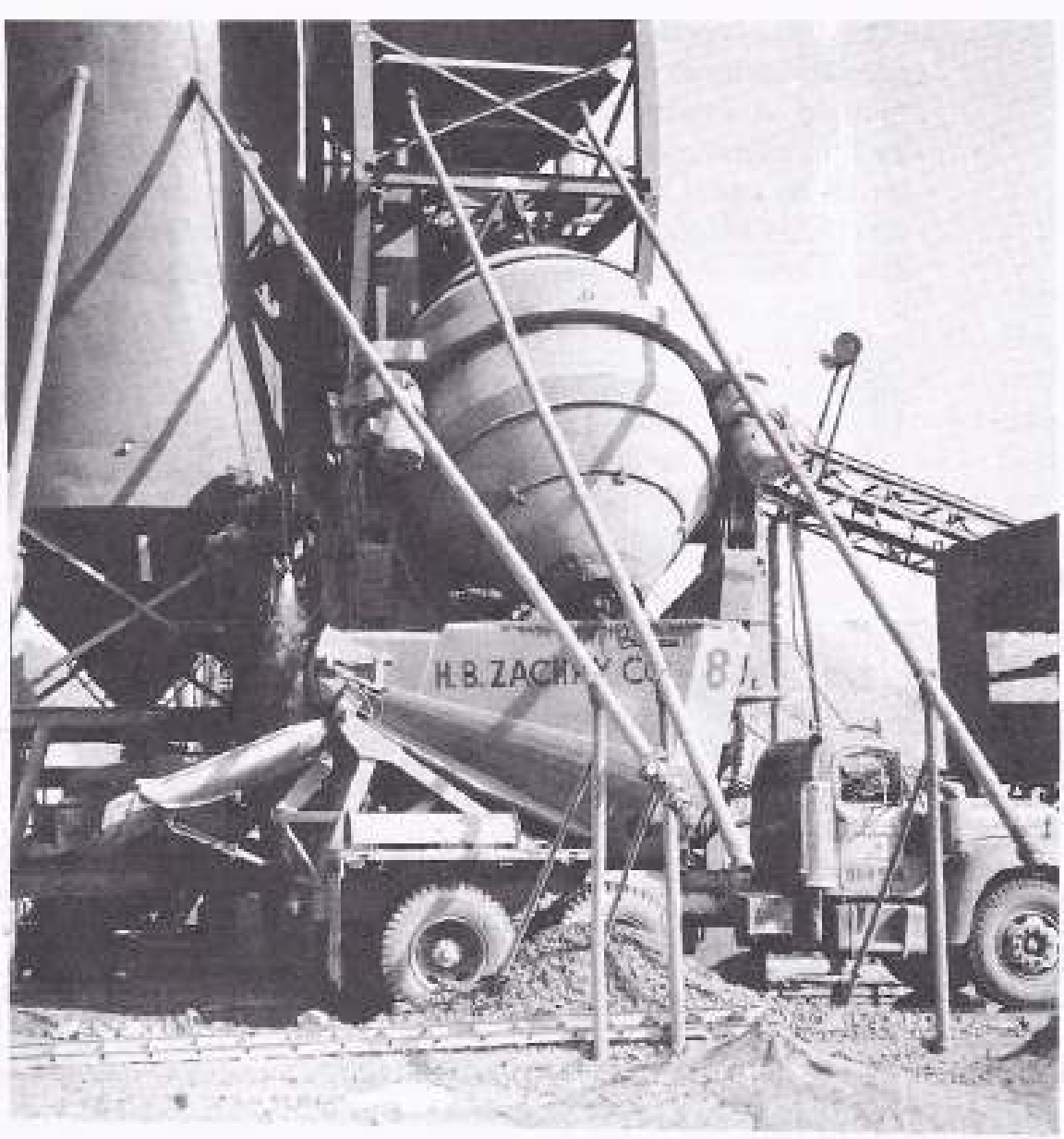

FIGURE 20-14 Tilting-drum mixer discharging concrete into agitating body truck. (Courtesy Wire Reinforcement Institute.)

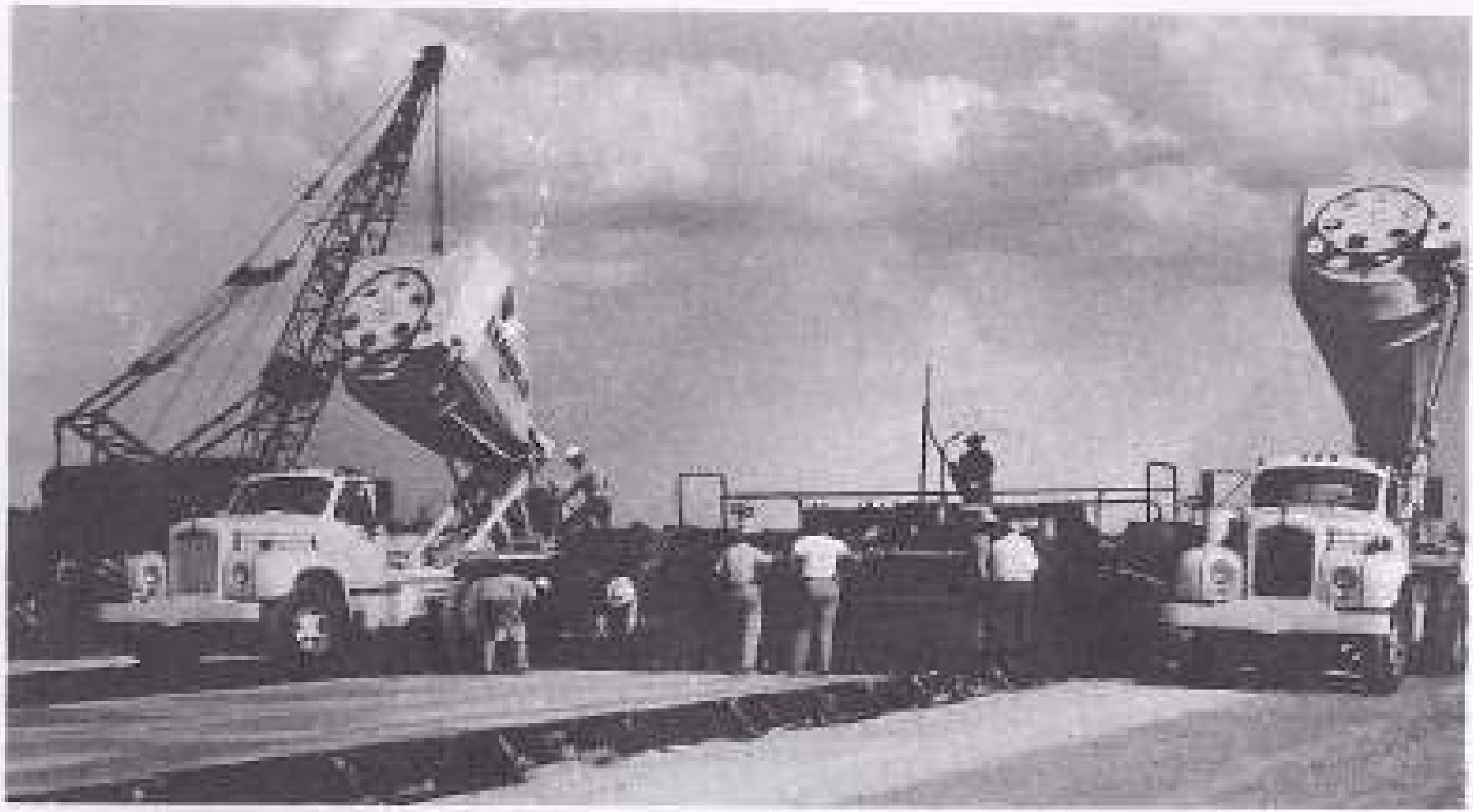

FIGURE 20-15 Agitating-body trucks discharging concrete into hopper-type spreader. (Courtesy *Engineering News-Record.*)

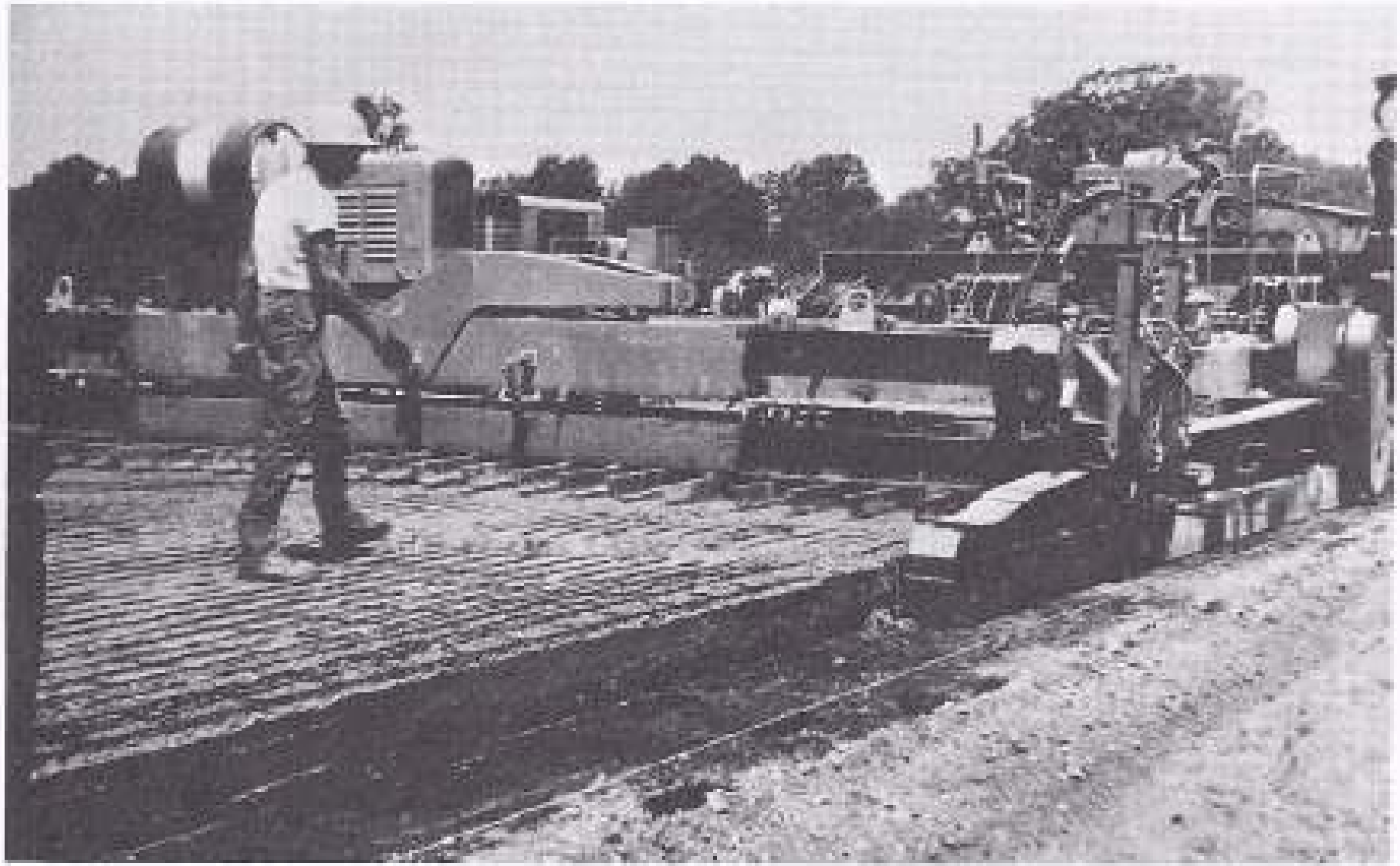

FIGURE 20-16 Blades of mesh placer push and vibrate reinforcing steel into fresh concrete. (Courtesy Portland Cement Association.)

FIGURE 20-17 Slipform paver at work on an interstate project. (Courtesy Portland Cement Association.)

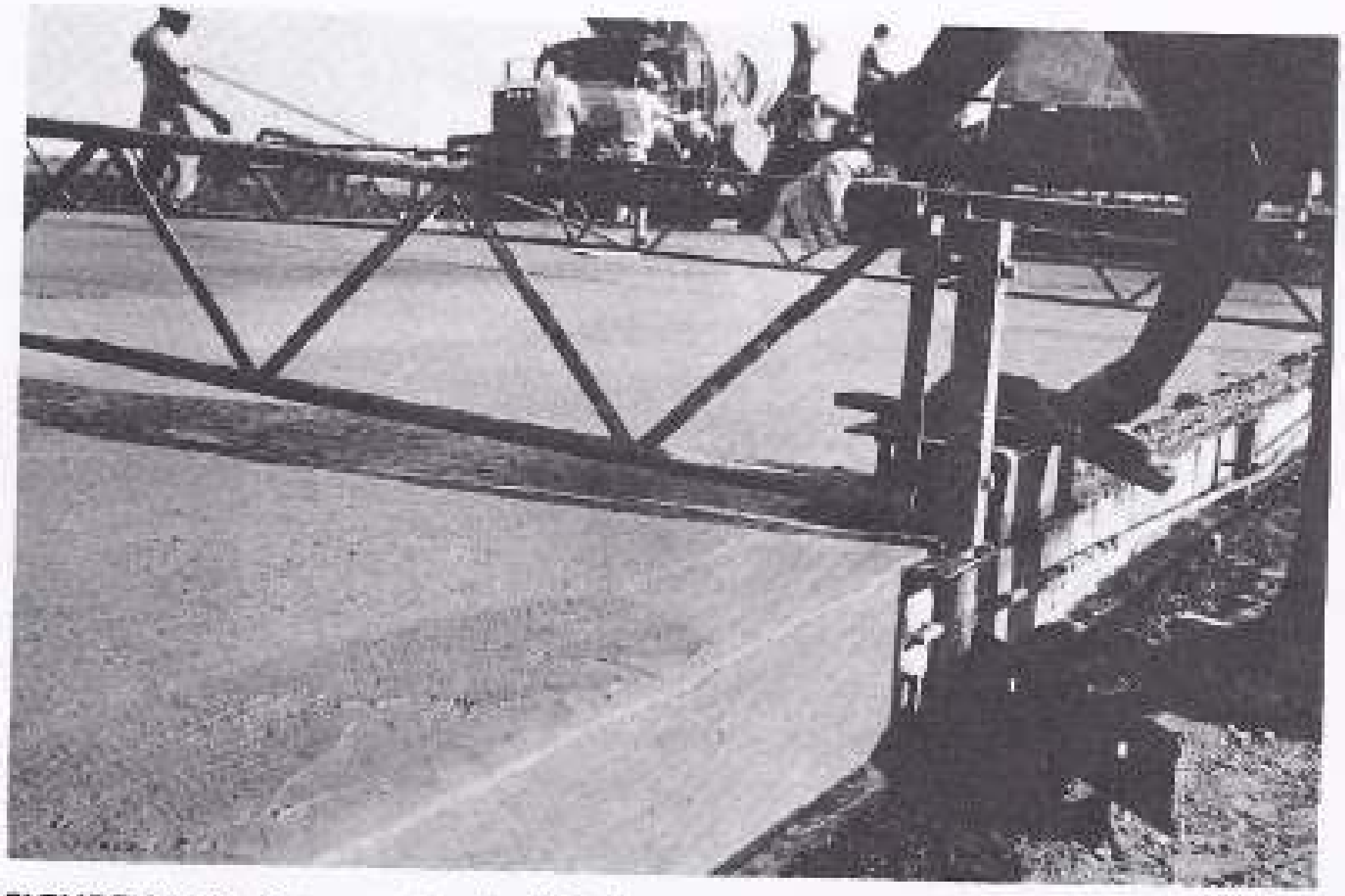

FIGURE 20-18 Pavement edge left by trailing form of slipform paver. (Courtesy Wire Reinforcement Institute.)

FIGURE 20-20 Concrete saw with a diamond blade cutting a pavement joint. (Courtesy Portland Cement Association.)