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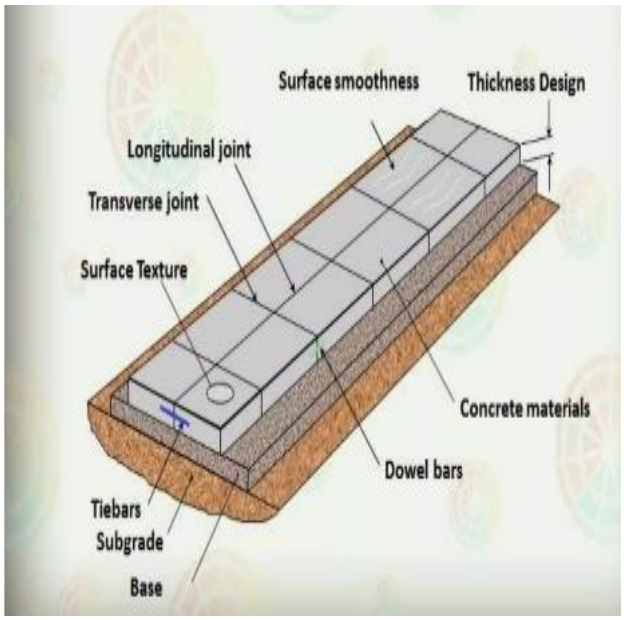
MINISTRY OF LABOR AND SKILLS

ROAD CONSTRUCTION AND MAINTENANCE

LEVEL – III

Based on September, 2023 Curriculum Version II



Module Title: Construction of Ridged Pavement

Module Code: EIS RCM3 09 0923

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Addis Ababa, Ethiopia

Bridges to Prosperity

HELVETAS Swiss Intercooperation

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LIST OF ACRONYMS

PPE -	PERSONAL PROTECTIVE EQUIPMENT
AASHTO -	AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS
CRS-	CATIONIC RAPID SETTING
JPCP –	JOINTED PLAIN CONCRETE PAVEMENT
CRCP	CONTINUOUS REINFORCED CONCRETE PAVEMENT
ASTM -	AMERICAN SOCIETY FOR TESTING AND MATERIALS
JRCP	JOINTED REINFORCED CONCRETE PAVEMENT
PCP	PRE STRESSED CONCRETE PAVEMENT
CLFP-	CONVENTIONAL LAYER FLEXIBLE PAVEMENT
ENPDM -	ETHIOPIAN NATIONAL PAVEMENT DESIGN MANUAL
RCCP	ROLLER COMPACTED CONCRETE PAVEMENT
CIP	CAST-IN-PLACE
PCC	PORTLAND CONCRETE CEMENT
HAVS-	HAND-ARM VIBRATION SYNDROME
CBR –	CALIFORNIA BEARING RATIO
ERA-	ETHIOPIAN ROAD AUTHOR

Introduction to this module

This module deals with the skills and knowledge and Attitude of Construction of Rigid Pavement Plan and prepare work ,Identify of Rigid Pavement, Conduct pre paving inspection, Identify spacing of tie bars for transverse & longitudinal contraction joints, Identify spacing of tie bars and Cut material, Screed/level concrete and clean up

Rigid pavements are those which posses note worthy flexural strength or flexural rigidity. In rigid pavement the stresses are not transferred from the grain to grain to the lower layers. The rigid pavements are made of Portland cement concrete either plain, reinforced or pre-stressed concrete.

In this module, the main principles involved in this work are covered in a generalized manner. Some detail of small scale concreting work, which a road worker might be required to undertake, is given at the end of the module.

This module covers the units:

- Planning and preparing work
- Types of Rigid Pavement
- pre paving inspection
- Spacing tie bars transverse & longitudinal joints
- Spacing Tie bars construction joints and Cut material
- Concrete work

Learning objectives of the Module

At the end of this session, the students will able to:

- Plan and prepare work
- Identify types of Rigid Pavement
- Conduct pre paving inspection
- Identify Space Tie bars transverse & longitudinal contraction joints
- Identify Space construct tie bars joints and Cut material
- Apply concrete work

Module Instructions:

For effective use this modules trainees are expected to follow the following module instruction:

1. Read the specific objectives of this unit.
2. Follow the instructions described below.

3. Read the information written in the information Sheets
4. Accomplish the Self-checks
5. Perform Operation Sheets
6. Do the “LAP test”

UNIT ONE: PLANNING AND PREPARING WORK

This learning unit is developed to provide the trainees the necessary information regarding the following content coverage and topics

- Basic concept of rigid pavement
- Compliance Documentation
- Worksite instructions
- Material quantity requirements
- Safety and Signage Requirements
- Plant ,Tools And Equipment
- Environmental Protection Requirements

This unit will also assist you to attain the learning outcomes stated in the cover page.

Specifically, upon completion of this learning guide, you will be able to:

- Define Basic concept of rigid pavement
- Identify compliance documentation
- Apply worksite instructions
- Identify material quantity requirements
- Identify Safety and Signage Requirements
- Select Plant ,Tools and equipment
- Apply Environmental protection requirements

1.1 Basic concept of rigid pavement

Rigid pavement is a type of pavement that is made of concrete. It is characterized by its high flexural strength, which allows it to withstand heavy loads without deforming or cracking. Rigid pavements are typically used for high-traffic roads, airports, and industrial areas.

Rigid pavements are typically divided into smaller sections by contraction joints. Contraction joints are designed to allow the concrete slab to expand and contract without cracking. The spacing of the contraction joints depends on the thickness of the concrete slab and the amount of traffic that the pavement is expected to carry.

The concrete slab is typically made of Portland cement concrete, which is a mixture of cement, water, sand, and gravel. The concrete is placed in a uniform layer and is compacted to the required density. The concrete is then cured for a specified period of time, which allows it to harden and gain its full strength.

Fig1.1 Rigid pavement road

1.2 Compliance Documentation

The compliance documentation for the construction of rigid pavements in Ethiopia according to the Ethiopian Roads Authority (ERA) Pavement Design Manual Volume II Rigid Pavements following:

- The ERA Pavement Design Manual Volume II Rigid Pavements: This manual provides the requirements for the design, construction, and maintenance of rigid pavements in Ethiopia.
- A quality control plan: This plan should outline the procedures that will be used to ensure that the pavement is constructed in accordance with the ERA standards.
- A testing plan: This plan should outline the tests that will be conducted to verify the quality of the materials and workmanship.
- A construction record: This record should document the construction process and the materials and workmanship used.
- As-built drawings: These drawings should show the final condition of the pavement after construction.

1.2.1 Standard Document procedures

The ERA standards document procedures for the construction of rigid pavements in Ethiopia are as follows:

1. Preliminary studies: This involves conducting a preliminary investigation of the site to determine the soil conditions, the amount of traffic that the pavement is expected to carry, and the desired lifespan of the pavement.
2. Design: This involves developing a detailed design for the pavement, including the thickness of the concrete slab, the type of jointing system, and the drainage system.
3. Construction: This involves constructing the pavement in accordance with the design, including the preparation of the sub grade, the placement of the concrete slab, and the curing of the concrete.
4. Quality control: This involves monitoring the construction process to ensure that the pavement is constructed in accordance with the standards.
5. Testing: This involves testing the materials and workmanship used in the construction of the pavement to ensure that they meet the standards.
6. Maintenance: This involves maintaining the pavement to ensure that it remains in good condition.

Important characteristics in determining the cause and effect relationship on why pavements perform as they do include the following:

- The strength of the pavement structure.
- The thickness and types of materials in the pavement structure.
- The strength, elastic, and plastic properties of the pavement materials.
- The magnitude and volume of wheel loads applied to the pavement. o The response of the pavement structure to load.
- The climate characteristics at the site.
- The condition of a pavement as a function of its roughness and features related to fracture, distortion, and disintegration of the surface materials.

Must be carefully followed and documented during ambient monitoring & should include following details:

A. Location of sampling station(s)
B. Records of meteorological conditions
C. Use of recommended sampling equipment
D. Careful determination of gas flow rate and sample time
E. Noting of any unusual conditions which may affect sample

1.2.2 Labor laws and regulations

A. Employment policy

One of the aims of the government of Ethiopia is to fully involve local people in the construction, rehabilitation and maintenance of construction works as cost effectively as possible. Temporary laborers and some skilled labor required for the construction works will therefore be recruited from the locality of the site.

When construction, rehabilitation or maintenance of a road, section of road, is completed, the work site will move to another location and the causal labour force will be discharged.

Women will be offered equal opportunities as men for employment, and the recruitment process must clearly demonstrate.

B. Laws and regulations

Laws and regulations apply to flexible pavement work:

Building codes: typically standards for the construction of pavements and structures. These codes requirements for the materials used the thickness of the pavement, and the methods of construction.

Environmental regulations: restrict the use of certain materials in pavement construction, such as materials that contain hazardous substances. Require the construction of certain features, such as storm water management systems, to minimize the impact of pavement construction on the environment.

Labor laws: wages and working conditions for workers involved in pavement construction. They require employers to provide workers with safety training and equipment.

Contracting laws: typically govern the process of awarding contracts for pavement construction. These laws may require that contracts be awarded through a competitive bidding process and that the contracts be in writing.

Inspection laws: require that pavement construction be inspected by a qualified inspector to ensure that it meets the required standards.

laws and regulations applicable as follows:

- Equality
- Freedom from forced labor
- Freedom of association
- Minimum age
- Minimum wage
- Protection of wage
- Safety and health

1.3 Worksite instructions

Work instructions are integral parts of constructing and monitoring flexible pavement projects. The processes involved dictate the overall operational efficiency and quality standard compliance of the project.

Instructions can be detailed in construction plan layouts, drafted specifications, design models, and operating procedures. Once these instructions are procured, the team needs to confirm those, ensuring they are coherent, achievable, relevant, and align with the project's scope and objectives.

Work instructions are key documents to reference when internal or external non conformances are identified. Make the review of the work instructions part of the corrective action process.

Construction planning as they relate to construction productivity and closure windows:

1. Selection of the construction closures and windows
2. Sequence of construction activities
3. Preliminary estimation rates
4. Job specific constraints

Confirming Work Instructions- once work instructions are obtained, it is imperative to confirm their accuracy and relevance. Obtain the project plans, specifications, and quality requirements.

Obtaining Work Instructions- Before commencing any construction project, it is crucial to obtain comprehensive work instructions. These instructions serve as a roadmap for the construction process, outlining the necessary steps and procedures. Work instructions can be obtained from various sources, project managers, engineers, or relevant authorities.

Applying Work Instructions After confirming the accuracy of work instructions, it is time to apply them during the construction process.

1.3.1 Work site instructions, day works & variation orders

Work Site instructions: Site instructions are written documents that provide specific instructions to the contractor on how to perform the work. They are typically issued by the project engineer or superintendent and should be clear, concise, and easy to understand.

Day works: Day works are a type of payment arrangement in which the contractor is paid for the actual time and materials used to complete the work. They are typically used for small, unplanned tasks or for work that is outside of the scope of the original contract.

Variation orders: Variation orders are written documents that authorize the contractor to deviate from the original contract. They can be issued by the project owner or engineer for a variety of reasons, such as changes in the scope of work, unforeseen conditions, or delays.

1.4 Material quantity requirements

The material quantity requirements for the construction of rigid pavements vary depending on the specific design of the pavement. Materials used in rigid pavement construction such as:

1. **Concrete**: is the main structural element of a rigid pavement. The amount of concrete required depends on the thickness of the slab and the area of the pavement.

Materials of concrete:

- Cement:
- Water:
- Aggregate
- Admixtures

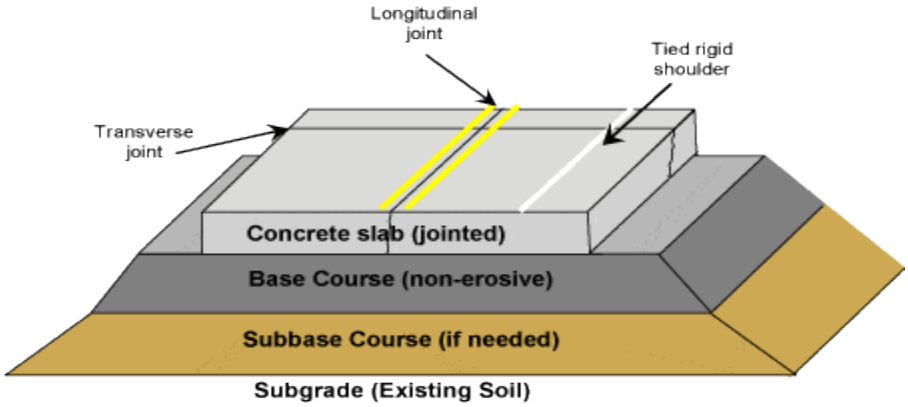


Fig1.2 Concrete used in rigid pavement

2. **Steel reinforcement:** used to strengthen the concrete slab and prevent it from cracking. The amount of steel reinforcement required depends on the thickness of the slab, the amount of traffic that the pavement is expected to carry, and the desired lifespan of the pavement.

   The main types of steel reinforcement use in concrete:

   - Deformed bars
   - Wire mesh
   - Strands
   - Pre stressed bars

Fig1.3 Steel reinforcement used in rigid pavement

3. **Sub base:** is the layer of material that is placed below the concrete slab. It helps to distribute the load from the concrete slab and prevent it from sinking into the sub grade. The type and thickness of the sub base material depends on the soil conditions and the amount of traffic that the pavement is expected to carry.

The materials use sub base in rigid pavement

- Crushed stone:
- Gravel:
- Sand:
- Recycled materials:

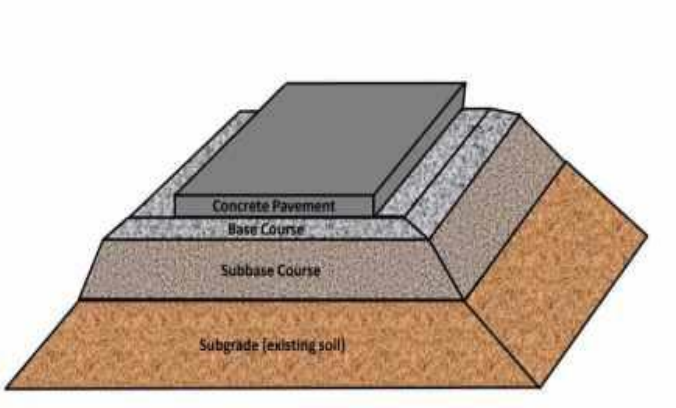


Fig1.4 Sub base used in rigid pavement

4. **Sub grade:** is the natural soil that the pavement is constructed on. It must be compacted to the required density to support the weight of the pavement.

The materials use sub grade in rigid pavement:

- Selected fill
- Cement-treated soil
- Geo synthetics soil
- Natural soil:

5. **Joint sealer:** A joint sealer is used to prevent water and other fluids from penetrating the joints between the concrete slabs. Materials use joint sealer in rigid pavement is Rubber**,** Epoxy, Polyurethane:

Fig1.5 Joint sealer used in rigid pavement

Fig1.6 joint sealer

Drainage system: A drainage system is used to remove water from the pavement. The drainage system typically consists of a network of pipes that are buried below the pavement. Materials use in drainage systems for rigid pavement

- Cement concrete pipes:
- Bituminous pipes
- Plastic pipes: Geo textiles:
- Drainage matting:

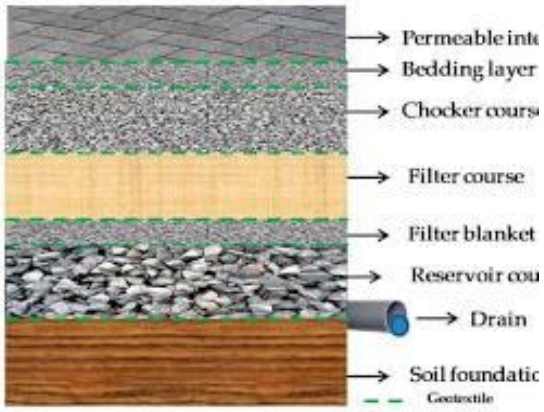


Fig 1.7 Drainage system used in rigid pavement

1.5 Safety and Signage Requirements

The construction of a rigid pavement is a complex and hazardous undertaking. There are many potential hazards associated with this type of construction, traffic accidents, falls, struck-by objects, and exposure to hazardous materials. To protect workers and the public, it is essential to implement appropriate safety and signs requirements.

Traffic control: Traffic control is essential to ensure the safety of motorists, workers, and pedestrians. Traffic cones, barricades, and signs should be used to warn motorists of the construction zone and to direct traffic around the work area.

Personal protective equipment (PPE): All workers should wear appropriate PPE, such as hard hats, safety glasses, gloves, and steel-toed boots. This will help to protect them from injury in the event of an accident.

Excavation and trenching: When excavating or trenching, it is important to ensure that the edges of the excavation are properly sloped and that there are adequate barricades to prevent people from falling in.

Workers: All workers should be trained in the safe operation of equipment and the specific safety requirements for the construction of a flexible pavement.

Signage: Proper signage should be used to warn motorists and pedestrians of the construction zone and to direct traffic around the work area. Signs should be placed in a timely manner and should be

clearly visible to motorists and pedestrians.

All equipment operators must be trained in the use of their equipment (trucks, rollers, concrete mixers, quarrying and construction hand-tools). Equipment must be maintained in good condition and workers must be aware of that safety covers should be used over moving parts on machinery.

Employers must:

- Make 'assessments of risk' to the health and safety of the workforce, and to act upon risks they identify
- Appoint competent persons to oversee workplace health and safety
- Provide workers with information and training on occupational health and safety
- Operate a written health and safety policy

1.5.1 Signage application

1. Traffic sign a device mounted on a fixed or portable support whereby a specific message is conveyed by means of words or symbols, officially erected for the purpose of regulating warning, or guiding traffic.
2. Traffic signal a power-oriented traffic control device by which traffic is regulated, warned, or alternately directed to take specific actions.

As a road work contractor you are directly responsible for the safety of your workers and the road users. Whenever work is being carried out on or close to the carriageway, adequate measures have to be taken to warn and protect both road users and your workers by ensuring that:-

- The necessary temporary traffic signs and protection are provided and correctly located on site for the duration of the work,
- All equipment and vehicles are parked off the carriageway or behind protective barriers and signs, when not in use,
- No material is to be left in a dangerous location and that the road adjacent to the work site is kept clean and swept of any debris arising from the work,
- All excavations are protected for the benefit of all road users, equipment and workers,
- All operators are trained in the operation of their equipment,
- Operators and labourers are informed of the potential risks of and procedures for working with or close to machinery,
    - Traffic control operations are carried out properly and that road users are not unnecessarily delayed,

- Where work on the carriageway or shoulder remains unfinished overnight, then proper warning lights re to be arranged and, if necessary protected,
- All sites are to be left tidy and cleared of debris when the work is completed.

1.5.2 Signs and Safety Equipment

When working on the roadside or carriageway, traffic from both directions must be alerted. The following signs and barriers are useful for this purpose:

- Reversible 'Stop / Go' Signs
- Speed Limit Signs (30 Km/Hr)
- 'Men Working' Signs
- 'No Overtaking' Signs
- 'Road Narrows' Sign
- 'End of Restriction' Signs
- Lane Closure Barriers And
- Traffic Cones

Standard signs the following signs should be available for traffic control on site:

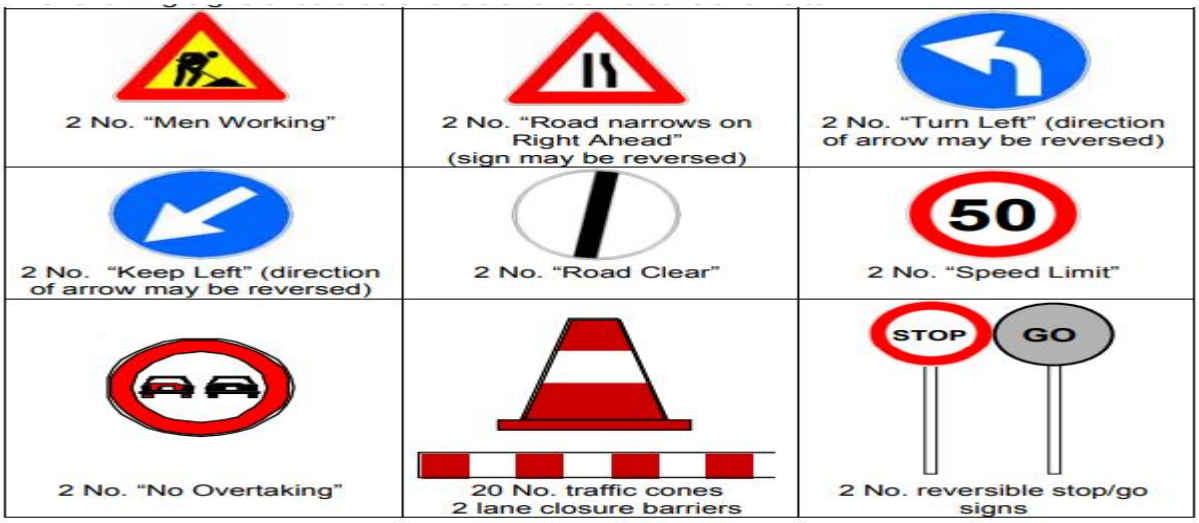


Figure1.8. Road signs used in Flexible Pavement works

These signs should be available as many as required. Reflective vests, workers should be issued with considering personal protective equipment depending on the work being undertaken such as

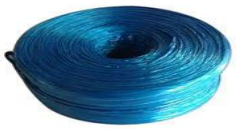
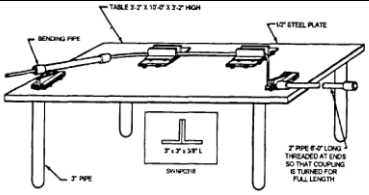
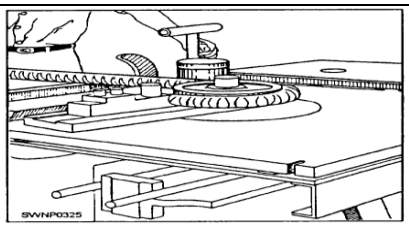
- Gloves
- Helmets
- Safety shoes
- Safety suit
- Dust Masks
- Goggles And
- Ear Muffs

Fig 1.9 Safety equipment

1.6 Tools, Plant and equipment

Table: 1 rigid pavement tools

Tools	Definition	Picture
steel Rakes	Rakes are used in road works for raking out vegetation from loose soil. Commercially produced rakes have 10 to 16 teeth, each about 75 - 100mm long, with an overall length about 400 - 450mm.	
Sledge Hammer	A sledgehammer is a tool with a large, flat, often metal head, attached to a long handle. The long handle combined with a heavy head allows the sledgehammer	
Spirit Level	Spirit levels are available in all different sizes. For construction work robust and long spirit levels are ideal.	

Hoes	The hoe, in addition to being very useful in agriculture, is also a commonly used tool when using labour-based work methods for rural road works.	
Strings	Alignment string /mason line/, sometimes called, Fish line, is a rope used to transfer horizontal & vertical alignments or lines, i.e.,	
Bar bending table .	For the job of bending, a number of types of benders can be used. Stirrups and column ties are normally less than No. 4, and you can bend them cold by means of the bending table	
Tape Measure	A great variety of tape measures exist. The most common length of tape measure used for setting out is 30 meters.	
Standard hook bending	Is accomplished on the turntable section located on top of the machine. Before you start any bending procedure, the turntable must be at the start position as shown in the figure below.	
Excavators:	Is used for the movement of the earth for road paver by doing its work of moving the earth while the main unit is stationary	
Scraper:	is a heavy equipment used to move large amounts of loose material, such as dirt, sand, or gravel. It has a long blade that is pulled by a tractor.	
Grader:	is a heavy equipment used to level and smooth surfaces. It has a long blade that is attached to a frame that can be raised or lowered.	

Bulldozer	is a heavy equipment used to push or pull objects. It has a long blade that is attached to a frame that can be raised or lowered.	
Tractor	is a heavy-duty vehicle that is used to pull or push loads. It has a large engine and wheels that are designed to grip the ground.	
wheel barrows	is a small, two-wheeled cart that is used to move materials. It is typically pushed by hand, but it can also be motorized.	
stipple devices	re used to create a textured surface on concrete. They can be made of rubber, plastic, or metal.	
concrete mixer	is a machine that is used to mix concrete. It has a rotating drum that mixes the cement, sand, gravel, and water together	
line pumps	are used to pump liquids, such as concrete, through pipes. They can be powered by electricity or gasoline.	
rakes	are used to level and smooth surfaces. They can also be used to collect materials.	
compressors	are used to pressurize air. They can be used to power tools, such as pneumatic drills, or to blow air away from surfaces.	

vibrators	Vibrators are used to compact materials, such as soil or concrete. They can be hand-held or powered.	
mechanized dumpers	are used to transport materials, such as concrete, dirt, and sand. They are typically powered by engines and have a large hopper that can be emptied by tilting the machine.	
screed boards	used to level and smooth concrete. They are typically made of wood or metal and have a long, straight edge.	
chutes,	used to transport materials, such as concrete, from one location to another. They can be made of wood, metal, or plastic and have a sloping surface that allows the materials to flow.	
Power trowels:	used to smooth and finish concrete. They are typically powered by electricity or gasoline and have a rotating blade that smooth the concrete surface.	

1.7 Environmental protection requirements

1.7.1 Organisational/project environmental management plan

Environmental protection planning is an important component of overall planning and implementation of mega-projects. The primary purpose of this Environmental Management Planning is to establish the environmental Protection Procedures to be implemented by staff, consultants and contractors. The purpose of the Environmental Management Plan is to:

- Ensure that commitments to minimize environmental effects are met
- Document environmental concerns and appropriate protection measures;
- Provide contingency plans for accidental events;
- Communicate changes in the program through the revision process and n Provide a reference to applicable legislative requirements.

1.7.2 Develop Waste management Plan

The waste management plan for each project will usually be the responsibility of the main contractor, and from this plan, specifications can be developed for bid/contractor packages, outlining procedures for salvage, reuse and recycling. It can also be used to provide clients with details of actual reuse/ recycling and disposal of waste.

In most cases, subcontractors would operate to the main contractor's plan. Where subcontractors have sole responsibility for their waste, they should complete their own waste management plan.

- The type and quantities of waste generated during operation
- Procedures to collect and dispose of waste
- Measure that will be implemented to minimize waste generation associated with the development
- A program for monitoring the effectiveness of these measures

A. Establish goals and objectives

Set broad goals and objectives related to the following:

- Eliminate the generation of waste, as a priority.
- Recycle and reuse waste that is created on the job.
- Use construction methods that allow for deconstruction.
- Use products and materials that reduce waste.

B. Estimate waste amounts

Forecast the types and percentages of waste that will be produced. Start off with your usual waste percentages - basis for comparison, use the ERA construction industry averages.

C. Set targets for reduction

Use the Resource Routing Calculator to determine what materials will be recycled. Set a target for each waste type; for example, reduce waste by 20% by the project's end.

D. Describe recycling/reuse methods

Identify the possibilities for reuse and recycling for each type of waste that is created and describe these where, how and when to handle waste materials. Attach a site plan with key areas marked if possible.

E. Material use and handling

Use this section to identify any recycled and second-hand materials or materials with recycled content being used on the project.

Also identify any special handling or storage measure to protect reusable and recyclable materials from damage and to ensure materials are consistent with requirements for acceptance by designated facilities

F. Project review

At the end of the project, add your ideas about strengths, weaknesses and suggested actions. See Reviewing the Process for more information.

G. Noise

Noise is unwanted sound judged to be unpleasant, loud or disruptive to hearing. From a physics standpoint, noise is indistinguishable from sound, as both are vibrations through a medium, such as air or water. The difference arises when the brain receives and perceives a sound.

Acoustic noise is any sound in the acoustic domain, either deliberate (e.g., music or speech) or unintended.

H. Vibration

Vibration in construction work Construction workers are at high risk of ill-health from using vibrating work tools. When using these tools vibration is transmitted into the worker's hands and arms – causing hand-arm vibration.

Regular hand-arm vibration can result in a number of conditions collectively known as hand-arm vibration syndrome (HAVS).

I. Dust and clean-up management

When it comes to working in construction, you have to be ready to get dirty. Whether you're renovating a building or constructing a new house, dust and dirt are part of the job. When there is an excess of dust and dirt traveling through the air though, it can become dangerous for your workers' health.

SELF-CHECK 1	Written Test

TEST I: MULTIPLE CHOICE

Direction: choose correct answer for the following question. Use the answer sheet provided to answer the following question

1. What is a work instruction?

A) A general overview of a process

B) A specification of materials required for a project

C) A document that defines how to execute activities in detail using technology or resources

D) A document outlining the budget for a project

2. What materials are commonly used in Portland cement concrete for rigid pavements?

A) Portland cement and coarse aggregate only

B) Portland cement, coarse aggregate, fine aggregate, and water only

C) Portland cement, coarse aggregate, and water only

D) Coarse aggregate, fine aggregate, and steel reinforcing rods only

3. Which of the following is NOT an important characteristic in determining the cause and effect relationship of pavement performance?

A) The texture of the pavement.

B) The strength, elastic, and plastic properties of the pavement materials.

C) The strength of the pavement structure.

D) The climate characteristics at the site.

4. Which manual is not a complete document for the purpose of rigid pavement analysis and design?

A) PCA Pavement Design Manual

B) ERA Pavement Design Manual

C) Ethiopian National Pavement Design Manual

D) AASHTO Pavement Design Manual

5. What type of safety measures should be taken on a worksite?

A) Workers should not wear protective clothing.

B) Workers should wear masks at all times.

C) Warning signs or cones should be placed at each end of the work area.

D) Workers should work in close proximity to each other.

TEST II: TRUE OR FALSE

Direction: Write the correct answer in the blank space. Time allotted for each item is 1 minute and each Question carries 3 points.

1_____The primary purpose of the Environmental Management Planning is to establish the Environmental Protection Procedures to be implemented by staff, consultants and contractors.

2. _____ Work instructions are not important to reference when non conformances are identified.

3. _____ Coarse aggregates used in Portland cement concrete can only be comprised of crushed gravel.

4. _____ the waste management plan should include procedures for salvage, reuse, and recycling.

5. _____ the maximum size of material retained in a No. 4 sieve is considered fine aggregate.

TEST III: SHORT ANSWER WRITING

Instruction: write short answer for the given question. You are provided 3 minutes for each question and each point has 5 Points.

1. What are the common types of highway making machinery for various operations involved in highway construction?
2. What is the purpose of a bulldozer during construction work?
3. What is the purpose of temporary traffic signs during road work construction?
4. What conditions must be satisfied by a power shovel during excavation and what is the output formula for power shovels?
5. What is the capacity of a scraper and what are its operations during excavation?

UNIT TWO: TYPES OF RIGID PAVEMENT

This learning unit is developed to provide the trainees the necessary information regarding the following content coverage and topics:

- Over view types of Rigid Pavements
- Jointed Plain Concrete Pavement
- Jointed Reinforced Concrete Pavement
- Continuous Reinforced Concrete Pavement
- Pre-Stressed Concrete Pavement

This unit will also assist you to attain the learning outcomes stated in the cover page.

Specifically, upon completion of this learning guide, you will be able to:

- Identify types of Rigid Pavements
- Construct Jointed Plain Concrete Pavement
- Construct Jointed Reinforced Concrete Pavement
- Construct Continuous Reinforced Concrete Pavement
- Construct Pre-Stressed Concrete Pavement

2.1 Over view types of Rigid Pavements

The main difference between the different types of rigid pavements is the amount of reinforcement that is used. JPCP has no reinforcement, JRCP has some reinforcement, CRCP has more reinforcement, and PCP has the most reinforcement.

The amount of reinforcement determines the strength of the pavement and the amount of traffic that it can support.

Concrete is a good choice for rigid pavements because it is strong, durable, and resistant to wear and tear. Asphalt concrete is a less expensive option, but it is not as strong or durable as concrete.

Rigid pavements are a good choice for roads that are expected to carry heavy traffic.

Compared to flexible pavement, rigid pavements are placed either directly on the prepared sub-grade or on a single layer of granular or stabilized material.

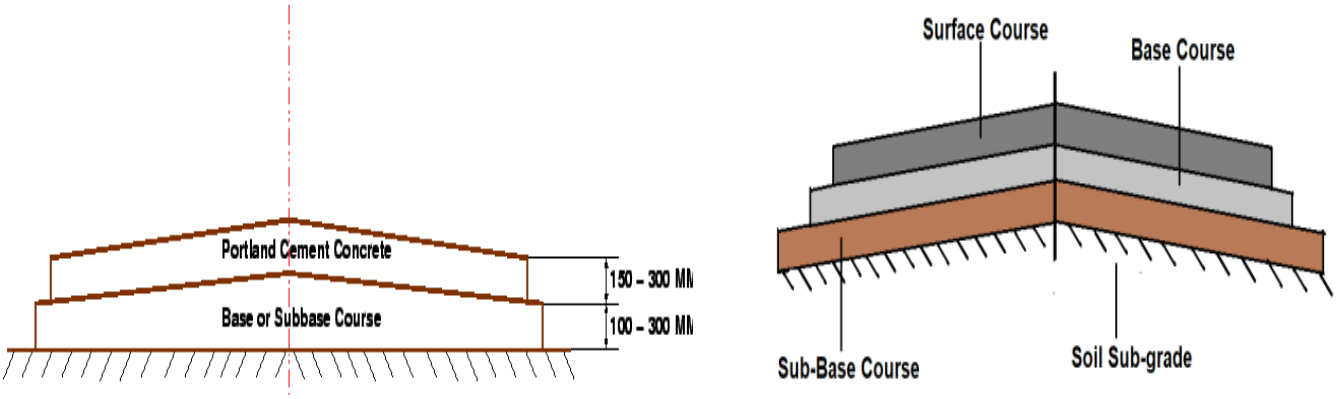


Figure 1.10 Typical Cross section of Rigid pavement

Type of Rigid Pavement	Reinforcement	Joints
Jointed plain concrete pavement (JPCP)	None	Yes
Jointed reinforced concrete pavement (JRCP)	Steel bars	Yes
Continuous reinforced concrete pavement (CRCP)	Steel bars	No
Pre stressed concrete pavement (PCP)	Steel bars	No

2.2 Jointed plain concrete pavement (JPCP)

Jointed Plain Concrete Pavements (JPCP) is the simplest type of rigid pavement. It has no reinforcement and is only jointed to allow for expansion and contraction. JPCP is the most common type of rigid pavement and is used for low to medium traffic volume roads. Specific to all concrete pavements, the phenomenon of cracking occurs when the concrete is exposed to several thermal and mechanical actions due to early-age shrinkage or expansion, temperature gradient, traffic stresses or possible soil movements.

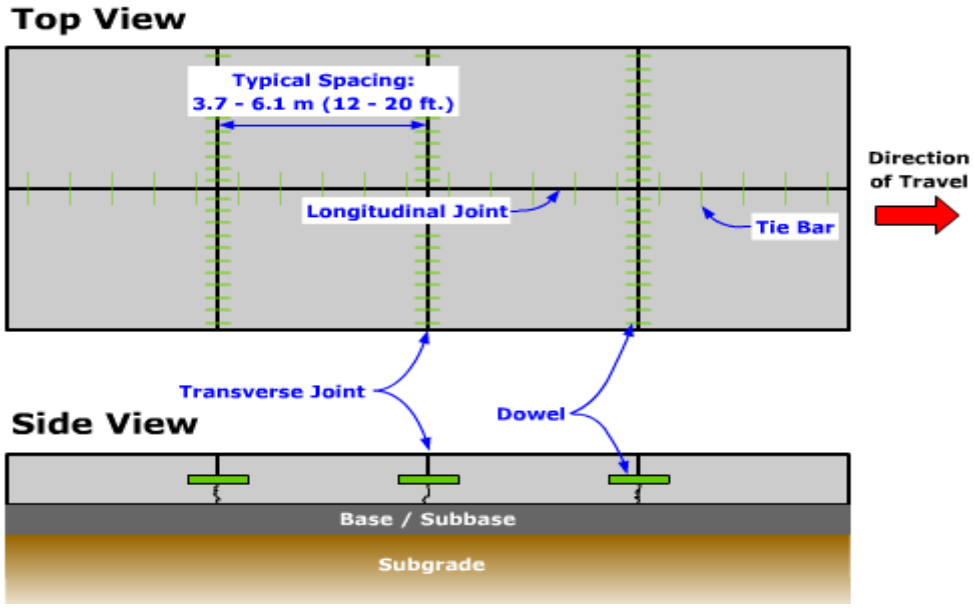


Figure1.11 Jointed plain concrete pavement (JPCP).

Jointed plain concrete pavement (JPCP, Figure 1.11) uses contraction joints to control cracking and does not use any reinforcing steel.

Transverse joint spacing is selected such that temperature and moisture stresses do not produce intermediate cracking between joints.

This typically results in a spacing no longer than about 6.1 m (20 ft.). Dowel bars are typically used at transverse joints to assist in load transfer. Tie bars are typically used at longitudinal joints.

Layers of Jointed plain concrete pavement (JPCP)

- Surface course: 20 to 30 cm thick concrete slab
- Base course: 5 to 10 cm thick granular material
- Sub base course: 10 to 15cm thick granular material
- Sub grade: compacted and graded soil

Properties

- Crack Control

Contraction joints, both transverse and longitudinal

- Joint Spacing

Typically between 3.7 m and 6.1 m) Due to the nature of concrete, slabs longer than about 6.1 m (20 ft.) will usually crack in the middle.

Depending upon environment and materials slabs shorter than this may also crack in the middle.

- Reinforcing Steel

  None

- Load Transfer

Aggregate interlock and dowel bars. For low-volume roads aggregate interlock is often adequate. However, high-volume roads generally require dowel bars in each transverse joint to prevent excessive faulting.

2.3 Jointed Reinforced Concrete Pavement (JRCP)

Jointed reinforced concrete pavements (JRCP) contain steel mesh reinforcement (sometimes called distributed steel). In JRCP, designers intentionally increase the joint spacing and include reinforcing steel to hold together mid-panel cracks.

The spacing between transverse joints is typically 30 ft (9 m) or more with some agencies using spacing as great as 100 ft (30.5 m).

performance issues caused by the embedded steel being incapable of holding together mid-panel cracking and the resultant erosion/faulting of such cracks.

It has steel reinforcement bars that are placed in the concrete slab to improve its strength. JRCP is used for medium to high traffic volume roads.

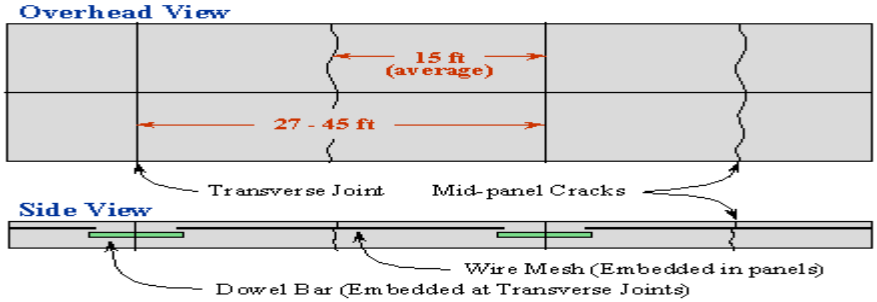


Fig1.12 Jointed reinforced concrete pavement

Layers of Jointed reinforced concrete pavement (JRCP)

- Surface course: 20 to 30 cm thick concrete slab
- Reinforcement bars: steel bars placed in the concrete slab
- Base course: 5 to 10 cm thick granular material
- Sub base course: 10 to 15 cm thick granular material
- Sub grade: compacted and graded soil

2.4 Continuously Reinforced Concrete Pavement (CRCP)

It is a type of rigid pavement that does not have any joints. It is made of a thicker concrete slab and is reinforced with steel bars that are placed throughout the slab. CRCP is used for high traffic volume roads and bridges.

Continuously reinforced concrete pavements (CRCP) are a type of concrete pavement that does not require any transverse contraction joints. Transverse cracks are expected in the slab, usually at intervals of 1.5 - 6 ft (0.5 - 1.8 m).

CRCP is designed with enough embedded reinforcing steel (approximately 0.6-0.7% by cross-sectional area) so that cracks are held together tightly.

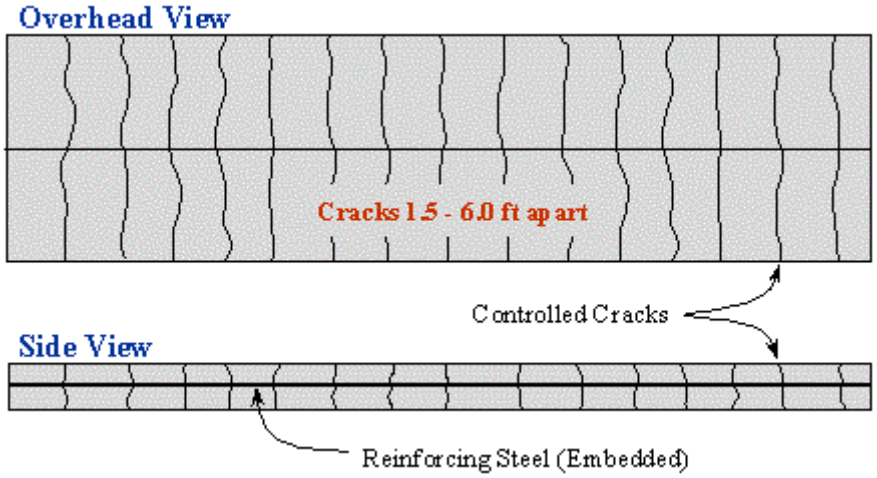


Fig1.13 Continuous reinforced concrete pavement

2.4.1 Basics of continuously reinforced concrete pavement (CRCP)

CRCP utilizes reinforcing steel to effectively eliminate transverse joints in favor of very tightly maintained cracks.

The reinforcing steel is used in combination with other design properties such as slab thickness and concrete materials to prevent traffic and environmental distresses.

The reinforcing steel results in cracks that have a shorter spacing than the joints in jointed plain concrete pavement due to increased restraint from the steel.

Transverse cracks in CRCP are typically 1.5 - 6 ft. apart. The steel holds the cracks extremely tight which helps promote load transfer through aggregate interlock (as well as through the steel itself).

CRCP placement

Placement of reinforcing steel on a curve

Close-up of reinforcing steel

Fig1.14. Continuously Reinforced Concrete Pavement Placement

2.4.2 Construction of CRCP

The most common method for steel placement is installing the steel and placers by hand before paving. The steel is held in place at the proper vertical location by chairs.

Transverse bars are also used to help hold the steel in place and make sure that any longitudinal cracks that develop are held tight.

The system of steel reinforcement, chairs, and transverse steel bars must be secure enough to ensure that it does not move as the concrete is placed around the steel either by hand or by a slip-form paver.

The system must also allow consolidation of the concrete to ensure proper performance. The reinforcing steel bars are lap-spliced together to build the length of the roadway.

The laps are typically staggered or skewed to prevent any compaction issues good consolidation and good performance is the use of a proper concrete mixture produced at a steady production rate that is vibrated properly. Limiting the heat of hydration and keeping concrete temperatures between 50 and 90 degrees.

fig 1.15 CRCP Hand Placement

fig1.16 Transverse Bar Assembly

Layers of Continuously Reinforced Concrete Pavement (CRCP)

- Surface course: 30 to 45 cm thick concrete slab
- Reinforcement bars: steel bars placed throughout the concrete slab
- Sub base course: 5 to 10 cm thick granular material
- Sub grade: compacted and graded soil

2.5 Pre Stressed Concrete Pavement (PCP)

It is a type of rigid pavement that uses pre stressed concrete to increase its strength. Pre stressed concrete is made by stretching the steel reinforcement bars before the concrete is placed. This makes the concrete stronger and more resistant to cracking. PCP is used for high traffic volume roads and bridges.

PCP systems are comprised of high-quality, prefabricated concrete panels that are formed offsite and installed during off-peak travel times.

The versatile approach can be used for rehabilitation of roadways, toll plazas, ramps, intersections, bridge approach slabs, and tunnels, in addition to new roadway construction.

Cast in plants under ideal conditions, precast panels are subjected to high quality control standards during the fabrication process, which results in a durable and ready-for-traffic road surface.

The required smoothness typically is achieved by routine grinding of the panels soon after placement.

PCP offers significant short- and long-term advantages, such as:

- Shorter installation time
- Reduced construction-related closures, and therefore reduced exposure of workers and drivers to work zone hazards
- Pavement is ready for traffic upon installation—no curing time
- Slabs are cast in plants under ideal conditions for optimum quality and durability
- Installation can take place at night or under adverse weather conditions, extending the construction season
- Longer-life performance than traditional cast-in-place (CIP) solutions

Fig1.17 Pre stressed concrete pavement (PCP)

Layers of Pre stressed concrete pavement (PCP):

- Surface course: 30 to 45 cm thick concrete slab
- Reinforcement bars: steel bars placed throughout the concrete slab
- Pre stressing tendons: steel cables that are stretched before the concrete is placed
- Sub base course: 5 to 10cm thick granular material
- Sub grade: compacted and graded soil

SELF-CHECK -2 WRITTEN TEST

TEST I: MULTIPLE CHOICE

Directions: Chose correct answer for the following Questions. Use the Answer sheet provided in the following

What is Jointed Plain Concrete Pavement (JPCP)?

A) A type of flexible pavement with no joints

B) A type of rigid pavement with steel mesh reinforcement

C) The simplest type of rigid pavement with contraction joints to control cracking and no reinforcement

D) A type of rigid pavement with thick concrete slabs

2. What is the main advantage of rigid pavements compared to flexible pavements?

A) Better ride quality

B) Lower construction cost

C) Easier maintenance

D) Higher resistance to heavy loads

3. Why does cracking occur in concrete pavements?

A) due to early-age shrinkage or expansion, temperature gradient, traffic stresses or possible soil movements

B) Due to poor quality materials

C) Due to lack of maintenance

D) Simply because of the nature of concrete

4. What is the purpose of contraction joints in Jointed Plain Concrete Pavements (JPCP)?

A) To control cracking

B) To increase load transfer

C) To allow for pavement flexibility

D) To hold together mid-panel cracks

5. How is load transfer achieved in Jointed Plain Concrete Pavements (JPCP)?

A) Through steel mesh reinforcement

B) Through aggregate interlock and dowel bars

C) Through thick concrete slabs D) Through compacted and graded soil

TEST II: TRUE OR FALSE

Direction: Direction: Write the correct answer in the blank space.

In circle Correct Answer. Use the Answer sheet provided in the following

1._____ a high level of sub-base restraint is required in CRCP to prevent expansion and contraction movements.

2. _____The cracks in CRCP have a longer spacing than the joints in JPCP.

3. _____The layer between the concrete and sub-grade in a rigid pavement can be called as base or sub-base course.

4. _____Dowel bars are used at longitudinal joints.

TEST III: SHORT ANSWER WRITING

Instruction: write short answer for the given question. You are provided 3 minutes for each question and each point has 5 Points.

1. Is there a requirement for the completion of the sub-base prior to concrete placing operations in rigid pavement construction?
2. What is the main difference between rigid and flexible pavements in terms of load transfer?
3. What is the purpose of sub-base in rigid pavement construction?
4. What is the thickness of Pre-Stressed Concrete Pavement (PCP) slabs typically?

OPERATION SHEET - 1	Continuously Reinforced Concrete Pavement

Operation Title: Continuously Reinforced Concrete Pavement

Instruction: Using the necessary tool, equipment and materials road marking according to drawing

Required tools, Materials and equipment:

Equipment and tools

- Concrete pump
- Forklift
- Joint saw
- Curing tent
- Hard hat
- Steel-toed boots
- Dust mask
- Gloves
- Safety glasses

Materials

- Steel reinforcement bars
- Concrete mix
- Joint sealant
- Curing compound

Precautions: - Wear safety glasses, hard hat, and steel-toed boots at all times.

Do not overload the concrete mixer or pump.

Keep the curing tent clean and free of debris.

Procedures:-

Step1. Prepare the sub grade.

Step2. Place the sub base course.

Step3. Place the reinforcement bars. Spaced30 cm apart.

Step4. Place the concrete.

Step5. Joint the concrete. Joints sawing cut at 10-foot intervals.

Step6. Seal the joints.

Quality Criteria:

- The concrete must have the correct slump and strength.
- The steel reinforcement must be installed correctly and evenly.
- The joints must be properly located and sealed.
- The surface of the concrete must be smooth and free of defects.

LAP TEST 1	Practical demonstration

Name: _____ Date: _____

Time started: _____ Time finished: _____

Instructions: As shown the Figure and detail below, you required to prepare the Setting-out of Base/Sub-base. The slope in the elevation is depending on the area as per instruction of the trainer. Use necessary templates, workshop, tools and materials you are required to perform the following tasks within 3 hours.

Task1. Prepare a concrete cylinder and a steel bar.

Task2. Clean the concrete cylinder and the steel bar with a wire brush.

Task3. Apply a bonding agent to the surface of the concrete cylinder and the steel bar.

Task4. Bond the concrete cylinder and the steel bar together.

Task5. Place the cylinder in a compression testing machine.

Task6. Apply a load to the cylinder until it fails.

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UNIT THREE: PRE PAVING INSPECTION

This learning unit is developed to provide the trainees the necessary information regarding the following content coverage and topics:

- Over view of pre-paving inspection
- Base course stability
- Establish offset pegs/profiles
- Steel reinforcement placement

This unit will also assist you to attain the learning outcomes stated in the cover page.

Specifically, upon completion of this learning guide, you will be able to:

- Define Over view of pre-paving inspection
- Checking base course stability
- Establishing offset pegs/profiles
- Checking steel reinforcement placement

3.1 Over view of pre- paving inspection

A pre-paving inspection is a visual inspection of the sub grade, base course, and sub base of a rigid pavement before the concrete slab is placed. The purpose of the inspection is to identify any potential problems that could lead to premature failure of the pavement.

The inspection is typically conducted by a qualified engineer or inspector. The inspector will look for things like:

- Unevenness in the sub grade
- Soft spots in the sub grade
- Voids in the base course
- Poor compaction of the base course
- Slopes that are too steep
- Water infiltration

If any problems are found, they must be corrected before the concrete slab is placed. This may involve adding material to the sub grade, compact the base course, or installing drainage systems.

A pre-paving inspection is an important step in ensuring the long-term durability of a rigid pavement. By identifying and correcting any potential problems before the concrete slab is placed, the inspector can help to prevent premature failure of the pavement.

3.2 Base course stability

Base course stability is the ability of the base course to resist deformation under load. It is an important factor in the design and performance of pavements.

The base course is the layer of material that is placed between the sub grade and the wearing course. It provides a stable foundation for the wearing course and helps to distribute the load from the traffic.

The stability of the base course is affected by a number of factors, including the type of material used, the thickness of the layer, and the compaction method.

The most common types of materials used for base courses are granular materials, such as crushed stone or gravel. These materials are strong and durable and can withstand a lot of traffic.

The thickness of the base course is also important. A thicker base course is more stable than a thinner base course.

The compaction method is also important. The base course should be compacted to the correct density to ensure its stability.

Base course stability can be measured in a number of ways, including the California bearing ratio (CBR) test and the resilient modulus test.

The CBR test is a measure of the resistance of the base course to penetration. The resilient modulus test is a measure of the ability of the base course to deform under load and then return to its original shape.

Base course stability is an important factor in the design and performance of pavements. A stable base course will help to prevent the pavement from cracking and rutting.

3.2.1 Stabilized base course

- The base course or granular base or stabilized base is the second layer from the top and is constructed using crushed aggregates.
- This course helps the surface course to take additional loads.
- It provides stable platform to construct rigid pavement.
- It is also useful to provide sub surface drainage system.
- In frost areas, the frost action can be controlled by the stabilized base course.
- It helps to control swelling of sub grade soil.
- The base course thickness should be minimum 100mm.

Figure1.18. Stabilized base course

Base layers stabilization & reinforcement requirements

The function of the base course varies according to the type of pavement under rigid pavements; the base course is used to:

(1) Provide uniform and stable support,

(2) minimize damaging effects of frost action,

(3) Provide drainage,

(4) prevent pumping of fine-grained soils at joints,

(5) prevent volume change of the sub grade,

(6) Increase structural capacity of the pavement, and

(7) Expedite construction.

3.3 Establishing offset pegs/profiles

Offset pegs and profiles are used in pre-paving inspection to establish the alignment and elevation of the pavement. They are typically made of wood or metal and are placed at regular intervals along the length of the pavement.

They are placed at a set distance from the edge of the pavement, and the distance between the pegs is equal to the width of the pavement.

The profiles are used to establish the elevation of the pavement. They are placed at a set elevation, and the elevation of the profiles is equal to the elevation of the finished pavement.

The steps of establish offset pegs/profiles of Pre- paving inspection:

1. Measure the width of the pavement and mark the location of the offset pegs at this distance from the edge of the pavement.
2. Drive the offset pegs into the ground at the marked locations.
3. Measure the elevation of the finished pavement and mark the location of the profiles at this elevation.
4. Drive the profiles into the ground at the marked locations.
5. Use a theodolite or total station to create a survey map of the pavement.

The following instruments are required for measurements with chain and tape:

(i)Arrows

(ii) Pegs

(iii) Ranging rods and ranging poles

(iv) offset rods

(v) Laths

(vi) Whites

(Vii) Plumb bobs

(viii) Line ranger

Arrows

when the length of the line to be measured is more than a chain length, there is needed to mark the end of the chain length.

Arrows are made up of 4 mm diameter steel wire with one end sharpened and other end bent into a loop. Length of an arrow is approximately 400 mm.

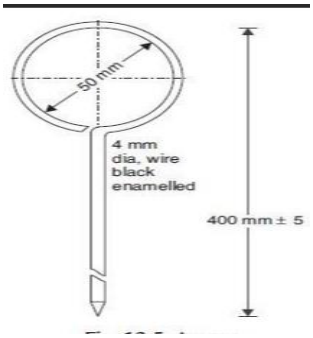


Figure1.20. Arrows line

Pegs

Wooden pegs are used in measuring a length of a line to mark the end points of the line. The pegs are made of hard wood of 25 mm Ã— 25 mm section, 150 mm long with one end tapered when driven in ground to mark station points they project about 40 mm.

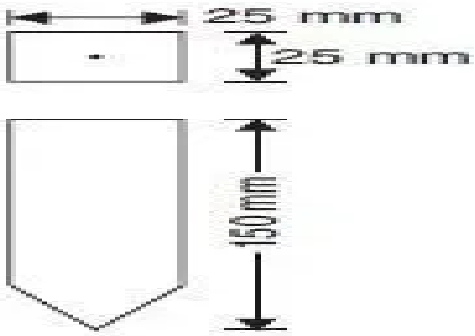


Figure1.21. Pegs

Ranging Rods and Ranging Poles

for ranging intermediate points along the line to be measured, ranging rods and ranging poles are used. Ranging rods are 2 to 3 m long and are made of hard wood.

Distance is more than 200 m, for clear visibility they may be provided with multi colored flags at their top.

Their length varies from 4 m to 8 m and diameter from 60 mm to 100 mm. They are made of hard wood or steel. They are fixed in the ground by making 0.5 m holes and then packed to keep them vertical.

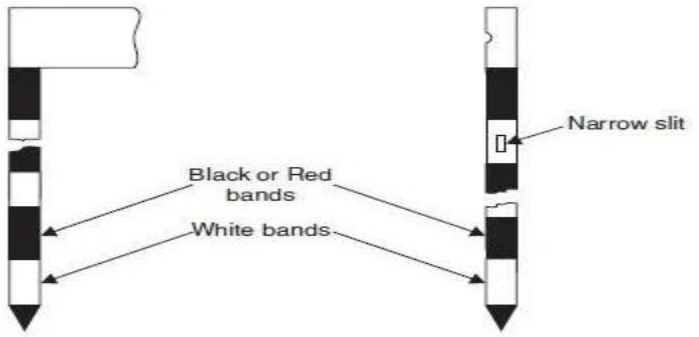


Figure1.22. Ranging Poles

Offset Rods

These rods are also similar to ranging rods and they are 3 m long. They are made up of hard wood and are provided with iron shoe at one end. A hook or a notch is provided at other end. At height of eye, two narrow slits at right angles to each other are also provided for using it for setting right angles.

Line Ranger

It is an optical instrument used for locating a point on a line and hence useful for ranging. It consists of two isosceles prisms placed one over the other and fixed in an instrument with handle. The diagonals of the prisms are silvered so as to reflect the rays.

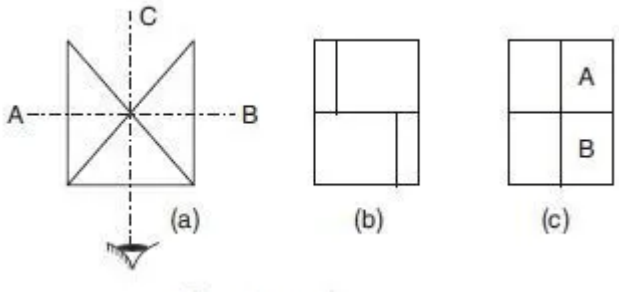


Figure1.23. Line Ranger

Construction Peg Offsets and Intervals

The offset and interval of the construction pegs will depend on the width of the pavement and the desired accuracy of the construction. For example, a wider pavement will require a larger offset and a smaller interval. A more accurate construction will require a smaller offset and a smaller interval.

Offset: The offset is the distance from the centerline of the pavement to the edge of the pavement. The offset is typically measured in feet or meters.

Interval: The interval is the distance between consecutive offset pegs. The interval is typically measured in feet or meters.

The construction peg offsets and intervals of pre-paving inspection of rigid pavement vary depending on the project common guidelines are as follows:

- The offset pegs should be placed at a distance from the edge of the pavement that is equal to the width of the pavement.
- The profiles should be placed at regular intervals along the length of the pavement, typically every 10 to 20 feet.
- The specific offset peg offsets and intervals will vary depending on the size of the project and the desired accuracy of the inspection.

Formation

The edge of formation is set out using the verge or shoulder strings and is placed by either stakeout from digital design model, string line radiation from the cross section reports or by offset from the existing centre line pegging.

The shoulder string is usually offset by 0.3 – 1.0m to allow compacting machinery to operate to the edge of the formation. If the verge string is set out, no offsetting is usually required.

These string lines form the basis of horizontal and vertical control for the pavement construction. It is the surveyor's responsibility to maintain a continuous control on alignment and levels.

The pegging interval for sub-grade should be no more than 20 meters and every 10 meters for sub-base and base-course.

Checking Elevation

Elevation checking is a critical part of the pre-paving inspection process. It involves checking the elevation of the existing pavement to ensure that it is level and within the specified tolerances.

There are a few different ways to check the elevation of the existing pavement. the specific method that is used to check the elevation of the existing pavement will depend on the size and complexity of the project.

To check during elevation checking of pre-paving inspection:

- The elevation of the existing pavement should be checked at regular intervals to ensure that it is level.
- The elevation of the pavement should be checked at all of the joints and cracks to ensure that they are properly aligned.
- The elevation of the pavement should be checked at the edges to ensure that it is sloped away from the road.
- The elevation of the pavement should be checked in areas where there is drainage to ensure that the water will flow away from the road.

3.4 Steel reinforcement placement

The placement of steel reinforcement is important to ensure that the concrete is properly reinforced. The steel reinforcement should be spaced correctly, aligned correctly, and covered with the correct amount of concrete.

The spacing of the steel reinforcement depends on the type of concrete being used and the expected loads on the concrete. The alignment of the steel reinforcement should be parallel to the centerline of the concrete member. The cover of the steel reinforcement is the thickness of the concrete that covers the steel.

Methods of steel reinforcement placement:

Manual placement: This method of steel reinforcement placement. The steel reinforcement bars are placed by hand and then tied together with wire.

Mechanical placement: This method uses a machine to place the steel reinforcement bars. The machine can place the bars more quickly and accurately than manual placement.

Prefabricated mats: This method uses prefabricated mats of steel reinforcement bars. The mats are placed in the concrete and then covered with concrete.

3.4.1 Pre-paving inspection for steel reinforcement placement

Proper spacing: The steel reinforcement should be spaced correctly. The spacing should be consistent throughout the pavement.

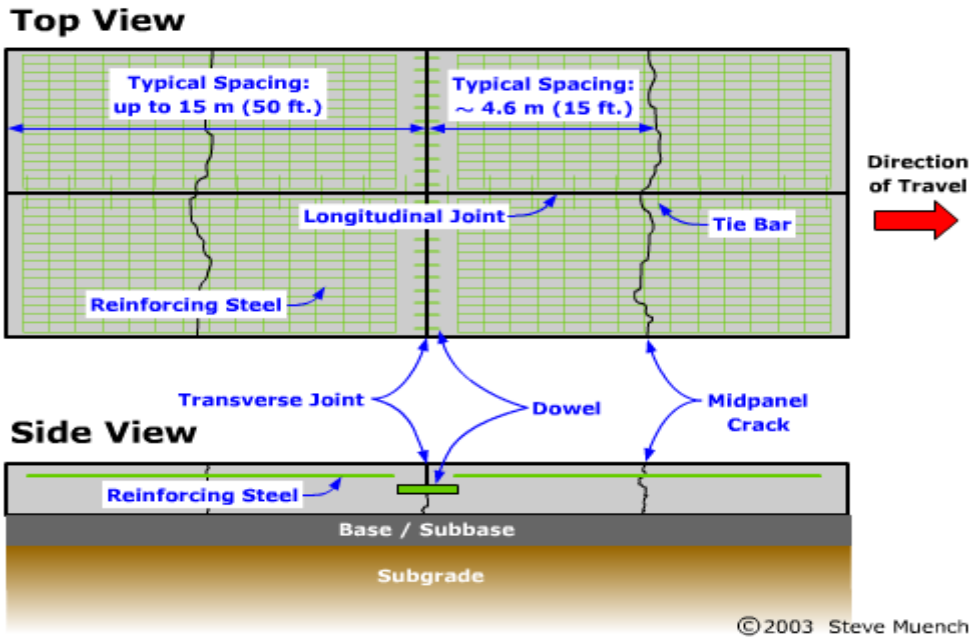
Proper alignment: The steel reinforcement should be aligned correctly. The reinforcement should be parallel to the centerline of the pavement.

Proper cover: The steel reinforcement should be covered with the correct amount of concrete. The

cover should be sufficient to protect the reinforcement from corrosion.

No gaps: there should be any gaps between the steel reinforcement bars. The bars should be tightly spaced together.

No rust. The steel reinforcement should not be rusty. Rust can weaken the reinforcement and make it more susceptible to corrosion.



Figur1.24 Proper spacing of steel reinforcement

Tie Bar Placement and Functions

1. Tie bars used for holding faces of rigid slabs in contact to keep aggregate interlock. They are also used in plain jointed concrete pavement to connect two lanes.
2. They are used to reduce transverse cracking.
3. Tie bars avoid separation and differential deflection in lanes.
4. They are not designed to work as a load transfer device

Figure1.25. Tie Bar placement

Tie bars are installed or inserted by hand or using a tie bar inserter attachment (in case of slip form pavement only) after one lane is paved at a time.

They are placed at mid-depth slab and bent back till the adjacent lane is prepared to be paved. When slip form pavers are used, tie bars are inserted on the slab edges that would become longitudinal joints.

3.4.2 Dowel Coating

- **Dowel Bar Placement**

Dowel bars can be placed either before PCC placement by using dowel baskets, or after PCC placement by using an automatic dowel bar inserter. Their placement is crucial to proper joint load transfer. Skewed, shallow or excessively corroded dowels can fail causing faulting and/or cracking at the joint.

- **Dowel Bar Preparation**

Dowel bars must be protected from corrosion although joints are sealed to keep water penetration to minimum, water will seep in overtime and, combined with deicing salts, may corrode unprotected bars. Typically dowel bars are protected from corrosion by the application of epoxy coating or stainless steel cladding .Additionally, dowels should be lightly coated with a lubricant such as grease or oil to prevent bonding with the PCC. The dowel must be free to slide in the concrete so that the two pavement slabs move independently, thus preventing excessive pavement stresses.

Fig.1. 26: Dowel bars

Dowel Baskets

Dowel baskets are simple truss structures used to hold dowel bars at the appropriate height before PCC placement. They are left in place after the PCC is placed but do not contribute to the pavement structure. When using dowel baskets, the dowels must be properly aligned and the dowel basket firmly anchored to the base course.

Fig.1.27: Dowel baskets

Dowel Bar Locations

The conventional approach to dowel bar placement in new pavement construction is to place 11 bars for a 12-foot lane, starting with the first bar located 12 inches from the pavement edge, with all of the bars placed 12 inches apart from the next adjacent bar.

3.4.3 Epoxy Coating

The dowel bar should be coated with an epoxy coating material selected from the official epoxy coating of steel. Once cured, the coating thickness must be at least 7 milliliters. Bowling or other deformation controls on dowel bars are not permitted to slide into the concrete.

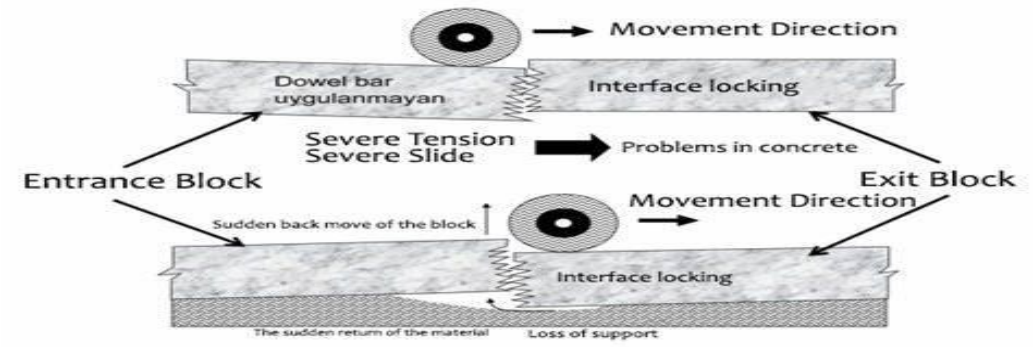


Fig.1.28: Dowel baskets

SELF-CHECK -3 WRITTEN TEST

TEST I: multiple CHOICE

Directions: Chose correct answer for the following Questions. Use the Answer sheet provided in the following

1. What factors determine the correct spacing of steel reinforcement in concrete?
   A) The type of prefabricated mats used and the expected traffic volume
   B) The expected loads on the concrete and the type of concrete being used
   C) The color of the concrete and the expected weather conditions
   D) The age of the concrete and the type of mechanical placement method used
2. Why is proper dowel bar placement crucial for joint load transfer?
   A) Skewed, shallow, or excessively corroded dowels can fail causing faulting and/or cracking at the joint
   B) Water penetration causes dowels to bond to the concrete
   C) Improperly placed dowels can cause excessive pavement stresses
   D) Dowels prevent aggregate interlock
3. What is the purpose of tie bars in concrete pavement?
   A) To increase the concrete's durability
   B) To add color to the concrete surface
   C) To prevent transverse cracking
   D) To provide load transfer
4. What is the purpose of tie bars in concrete pavement?
   A) To increase the concrete's durability
   B) To add color to the concrete surface
   C) To prevent transverse cracking
   D) To provide load transfer
5. How are dowel bars protected from corrosion in concrete pavement?
   A) They are coated with epoxy or stainless steel cladding
   B) They are covered with water-resistant sealant
   C) They are left exposed to the elements D) They are coated with a lubricant

TEST II: TRUE OR FALSE

Direction: Direction: Write the correct answer in the blank space. Use the Answer sheet provided in the following

1._____ the cover of steel reinforcement should be thick enough to protect it from corrosion.

2._____ Tie bars can reduce transverse cracking and avoid separation in lanes.

3. _____ Mechanical placement of steel reinforcement is less accurate than manual placement.

4. _____ Dowel bars must be protected from corrosion but should not be coated with a lubricant.

5. _____ Proper steel reinforcement spacing depends on the type of concrete being used and expected loads.

TEST III: SHORT ANSWER WRITING

Instruction: write short answer for the given question. You are provided 3 minutes for each question and each point has 5 Points.

1. Why is proper spacing of steel reinforcement important in concrete placement?
2. What are the benefits of mechanical placement of steel reinforcement over manual placement?
3. Why is it important for the steel reinforcement to be aligned parallel to the centerline of the pavement?
4. Why is dowel bar placement crucial to proper joint load transfer in concrete pavement?
5. How should dowel baskets be anchored to the base course in concrete pavement?

OPERATION SHEET 1	Establish offset pegs/profiles

Operation Title: Establish offset pegs/profiles

Instruction: Using the necessary tool, equipment and materials road marking according to drawing

Required tools and equipment:

- Arrows
- Pegs
- Ranging rods and ranging poles
- Offset rods
- Laths
- Whites
- Plumb bobs and
- Line ranger.

Precautions: - Always put on helmets, seat belts and safety equipment before starting work

- Never use mobile phones or ear phone while work always remember

Procedures:-

Step1. Monitor/Inspect the site, then survey and Lay-out as per plan.

Step2. Check the elevation as per plan and specification by survey, and then observe the tolerances.

Step3. Check the elevation while doing this item based on the lay-out or blow top as per instruction of the site engineer.

Step4. Check the temperature of the paint

Quality Criteria:

Clean the road surface, mark the lines accurately, temperature below 9 ℃ painting

LAP TEST 1	Practical demonstration

Name: _____ Date: _____

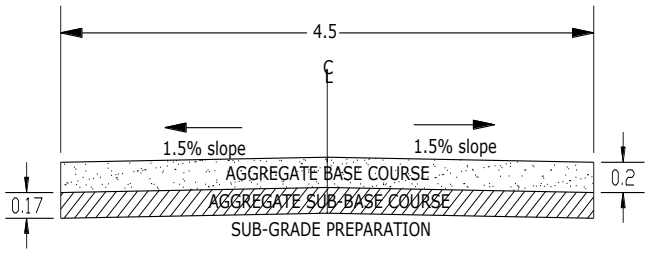
Time started: _____ Time finished: _____

Instructions: As shown the Figure and detail below, you required to prepare the Setting-out of Base/Sub-base. The slope in the elevation is depending on the area as per instruction of the trainer. Use necessary templates, workshop, tools and materials you are required to perform the following tasks within 3 hours.

Task1. Perform offset pegs/profiles

Task2. Monitor base/sub-base make sure the construction drawing

Figure Exercise:



Note:

1. The length is equal 1.5 meter
2. The dimension is all in meter

UNIT FOUR: SPACING TIE BAR TRANSVERSE & LONGITUDINAL JOINTS

This learning unit is developed to provide the trainees the necessary information regarding the following content coverage and topics:

- Overview Spacing Tie bars transverse & longitudinal joints
- Types of slab and load transfer
- Tie bar Longitudinal and Transverse construction Joints
- Dowel and tie Bars Joints Shape And Sealant
- spacing of tie bars and Cut material

This unit will also assist you to attain the learning outcomes stated in the cover page.

Specifically, upon completion of this learning guide, you will be able to:

- Define overview of Spacing Tie bar transverse & longitudinal joints
- Identify types of slab and load transfer.
- Identify Tie bar Longitudinal and Transverse construction Joints
- Place Dowel and tie Bars Joints Shape And Sealant
- Identify space of tie bars and Cut material

4.1 Overview of Spacing Tie bar transverse & longitudinal joints

The spacing of tie bars in transverse and longitudinal joints is an important factor in the design and construction of concrete pavements. The factors determining the spacing of tie bars in transverse and longitudinal joints:

- Type of pavement: will affect the amount of load that the tie bars need to transfer. For example, a concrete pavement with a high traffic volume will require more tie bars than a concrete pavement with a low traffic volume.
- Traffic volume: will affect the amount of stress that the tie bars need to resist. For example, a pavement with a high traffic volume will require more tie bars than a pavement with a low traffic volume.
- Climate: will affect the amount of expansion and contraction that the pavement will experience. For example, a pavement in a cold climate will require more tie bars than a pavement in a warm climate.

Tie bars are used in joints to transfer load from one slab to the next.

Transverse joints are joints that are placed perpendicular to the direction of traffic. The typically spaced at intervals of 30 to 45 cm in the width of the pavement.

Longitudinal joints are joints that are placed parallel to the direction of traffic. They are typically spaced at intervals of 60 to 90 cm in the thickness of the pavement.

The spacing of tie bars in transverse and longitudinal contraction joints depends on the following factors:

The spacing's for tie bars in transverse and longitudinal joints:

- Transverse joints: 6 to 12 inches (15 to 30 cm)
- Longitudinal joints: 12 to 24 inches (30 to 60 cm)

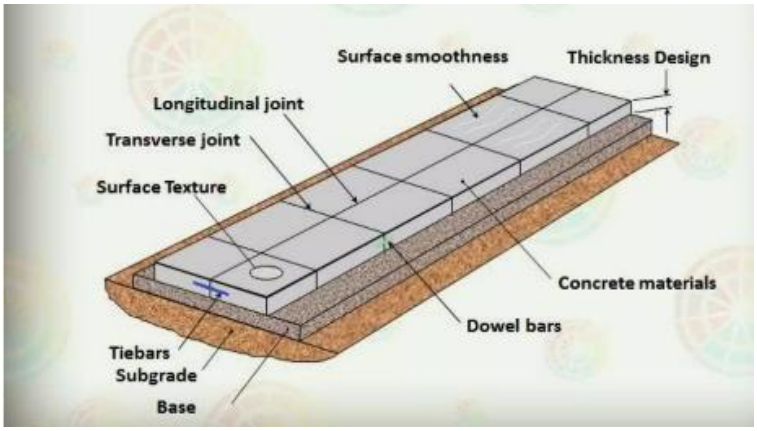


Fig.1.29: tie bars in transverse and longitudinal

4.1.1 Construction contraction Joints

Contraction joints are used to control the formation of cracks .Typically these are placed every 15-20 ft in the transverse direction and every 12-14 ft in the longitudinal direction. These joints utilize aggregate interlock as one form of load transfer, but they can also be dowelled to provide mechanical load transfer. Transverse contraction joints are typically dowelled and longitudinal contraction joints are typically tied together with a tie bar.

Longitudinal contraction joints are used to control cracking when more than 12-15 ft of pavement is being placed in one pass of a paver.

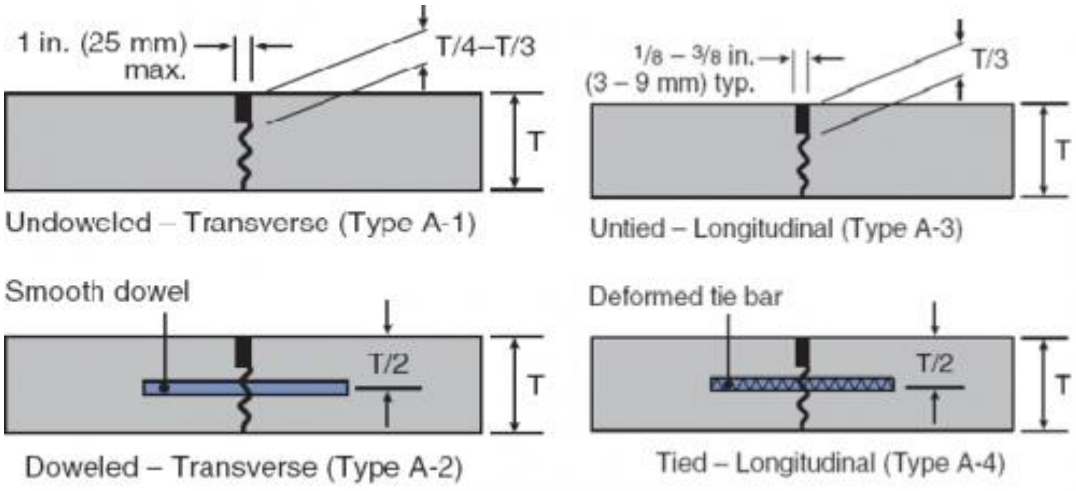


Fig.1.30 Contraction Joints

The types of construction contraction joints

Saw-cut joints: This is the most common type of contraction joint. It is created by sawing the concrete along the marked lines. The saw should be set to a depth that is equal to the thickness of the concrete.

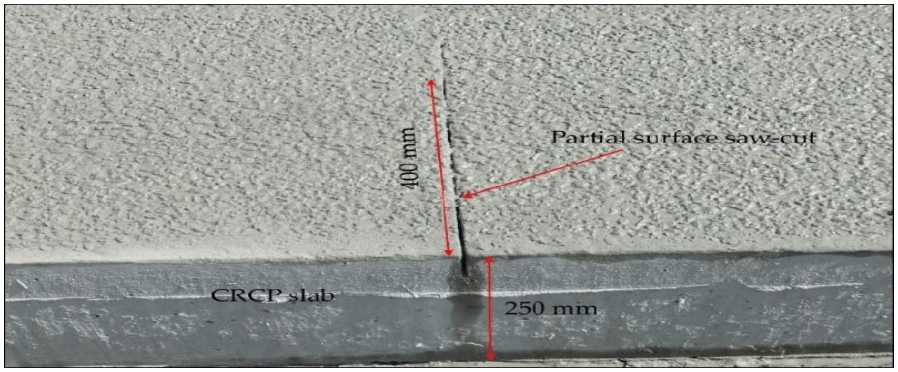


Fig1.31 Saw-cut joints in concrete pavement

Grooved joints: This type of contraction joint is similar to saw-cut joints, but the grooves are made using a grooving machine instead of a saw. The grooving machine creates a shallower groove than a saw, which makes it less likely to weaken the concrete.

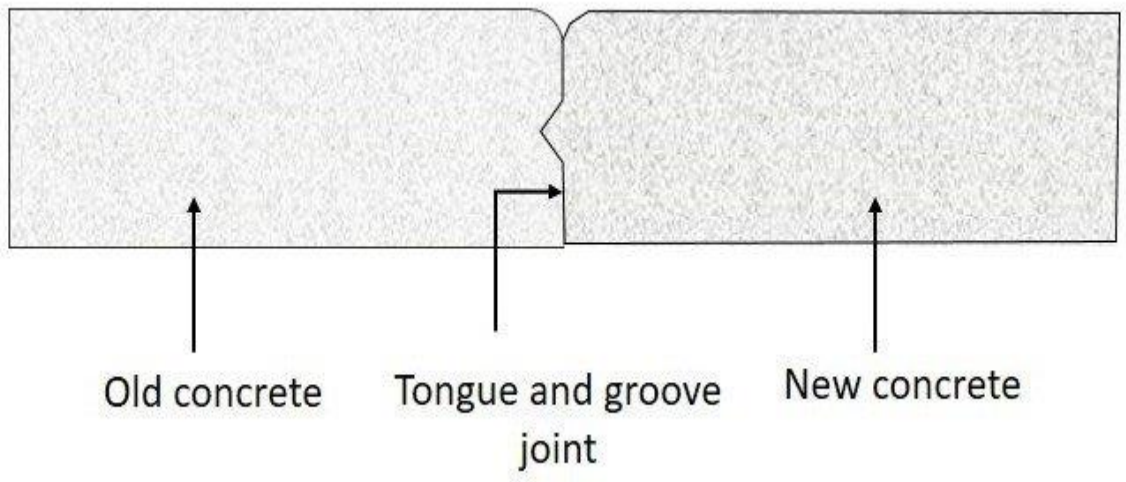


Fig 1.32 Grooved joints in concrete pavement

Contraction joint strips: This type of contraction joint uses prefabricated strips of contraction joint filler that are embedded in the concrete. The strips are made of a flexible material that can allow the slabs to expand and contract.

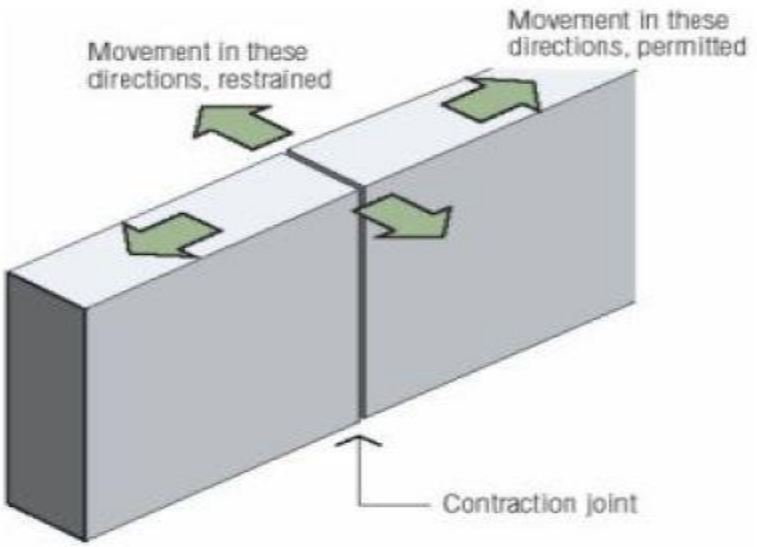


Fig 1.33 Contraction joint strips in concrete pavement

Expansion joint sealant: This type of contraction joint uses a sealant to fill the gap between the two slabs of concrete. The sealant should be flexible so that it can allow the slabs to expand and contract.

Fig1.34 Expansion joint sealant in concrete pavement

Doweled contraction joints: This type of contraction joint uses dowels to connect the two slabs of concrete. The dowels help to transfer load from one slab to the next and prevent the joints from opening up too much.

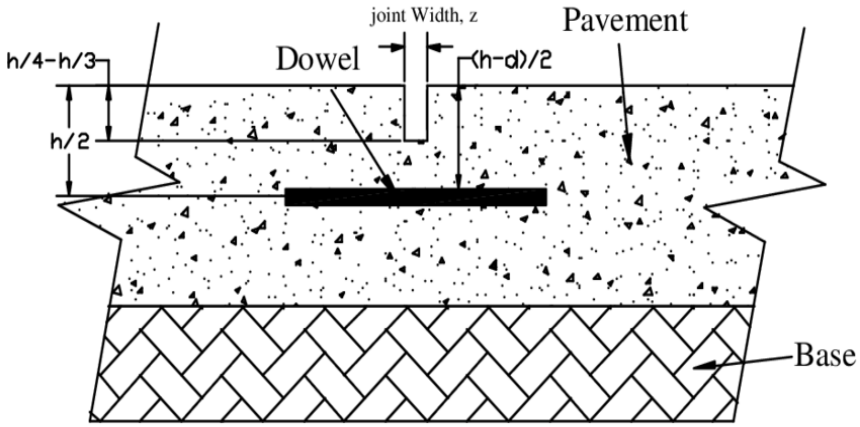


Fig1.35 Doweled contraction joints in concrete pavement

4.2 Types of slab and load transfer

The types of slabs and load transfer mechanisms used in rigid pavement are important factors that affect the performance and durability of the pavement. The best type of slab and load transfer mechanism for a particular application will depend on the specific conditions of the project**.**

Sandstone paving slabs

Sandstone paving slabs are one of the most accessible kinds of paving slabs in the market because of their variety of colors and durability. The silicon molecules are densely packed together, which accounts for its longevity, making it the paving slab of choice for most clients.

Porcelain Pavers slabs

Porcelain is manufactured by combining clay and other materials and then heating them at high temperatures in a furnace.

Limestone/Marble Paving Slabs

Limestone paving slabs meet all the criteria for being the finest kind of paving slabs available in the market: they are aesthetically pleasing, durable, and come in a broad variety.

Marbles are among the most expensive and eye-catching pavers available; they also come in various designs and may be used in both commercial and residential settings.

Slate Paving Slabs

When compared to sandstone and limestone, slate is a distinct natural stone. While sandstone and limestone are sedimentary rocks composed of grains, slate is a metamorphic rock with a layered structure.

Granite Paving Slabs

Granite, the second hardest natural stone after diamond, is a versatile stone used for several architectural purposes worldwide. Quality makes granite durable and prevents water from penetrating

Black Paving Slabs

Black paving slabs are a subtype of limestone paving slabs and not a unique category of slabs. People who like the color black and wish to keep things simple often choose black paving slabs for their outdoor surfaces.

Concrete Pavers Slabs

Concrete pavers are made from aggregates, sand, cement, pigments, and dyes. Though its production process varies, the mixture is normally pressed into a paver mold with minimal water.

Slab width

Rigid Pavement Concrete Slab Design to determine concrete slabs' behavior on the rigid pavement, a concrete slab design measuring 600×2000 mm was made with a thickness variation of 100 mm, 150 mm, and 200 mm. The slab width of a rigid pavement is typically between 0.30m and 60m Fig.1.35 & 36 show the dimensions and reinforcement of the concrete slab specimen and the rigid pavement structure model above the ground in a steel box. The concrete slab as the rigid pavement is placed on the ground as a sub grade; with a soil thickness of 30 cm. soil (sub grade) is used as elastic support with a certain CBR value.

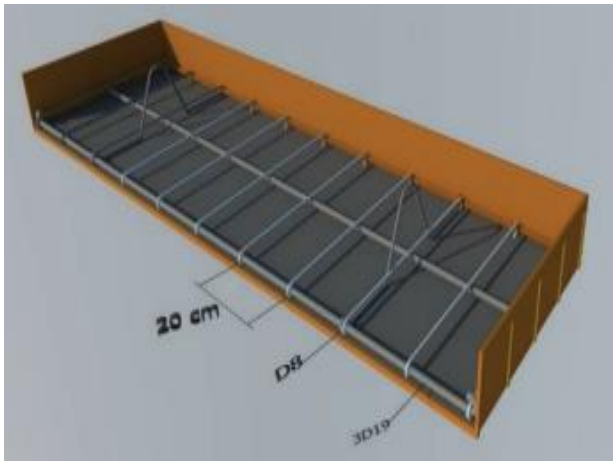


Fig.1.36. Dimensions and specimens of reinforced concrete slabs

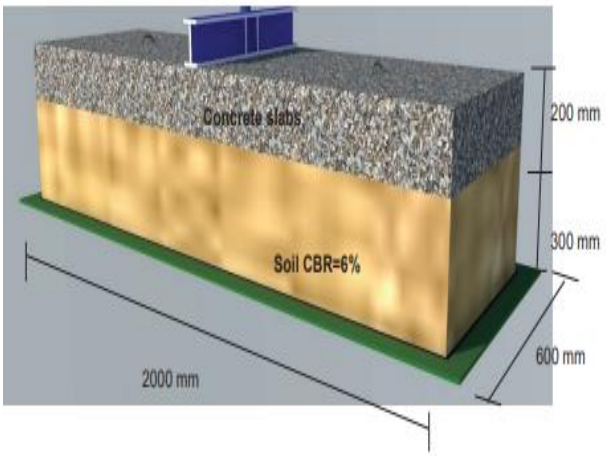


fig1.37. Model of rigid pavement structure above ground in a steel box

4.2.1 Load Transfer

A load is applied to a rigid pavement the load is transferred through the slab to the sub grade. The slab bends under the load, and the dowel bars help to transfer the load from one slab to the next. The aggregate interlock also helps to resist the movement of the slabs.

The load transfer capacity of a rigid pavement is determined by the thickness of the slab, the spacing of the joints, the type of reinforcement, and the properties of the sub grade. The thicker the slab, the more loads it can carry. However, a thicker slab is also more expensive.

The closer the joints are spaced, the more load transfer bars will be needed. However, a closer joint spacing also means more joints to maintain. The type of reinforcement used will affect the cost and performance of the pavement.

The properties of the sub grade will also affect the load transfer capacity of the pavement. A softer sub grade will require a thicker slab to carry the same load.

The load transfer in rigid pavements is achieved through a combination of three mechanisms:

1. Aggregate interlock: The aggregate particles in the concrete interlock with each other to resist the movement of the slabs.
2. Dowel bars: Dowel bars are steel bars that are embedded in the slabs and extend across the joints. The dowel bars help to transfer the load from one slab to the next.
3. Reinforcement: The steel reinforcement in JRCP helps to control cracking and improve the load transfer capacity of the pavement.

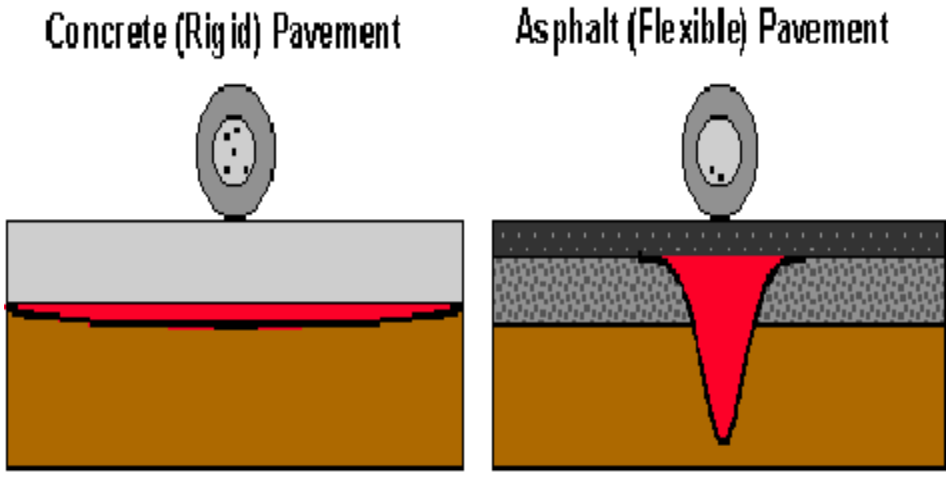


Fig1.38 Load transfer in rigid pavement

4.3 Tie bars Longitudinal and Transverse construction Joints

Tie longitudinal and transverse construction joints are used in concrete pavements to control cracking and to allow for the expansion and contraction of the pavement.

Longitudinal construction joints are placed parallel to the centerline of the pavement. They are used to control cracking that can occur due to the shrinkage of the concrete. Longitudinal construction joints are typically spaced every 30 to 45 m.

Transverse construction joints are placed perpendicular to the centerline of the pavement. They are used to control cracking that can occur due to the expansion and contraction of the pavement due to changes in temperature. Transverse construction joints are typically spaced every 9 to 15m.

Tie bars are steel bars that are embedded in the slabs and extend across the joints. The type of tie bar used will depend on the type of pavement and the traffic volume. In general, larger tie bars are used in pavements with higher traffic volumes.

Differences between tie longitudinal and transverse construction joints:

- Longitudinal construction joints are placed parallel to the centerline of the pavement, while transverse construction joints are placed perpendicular to the centerline of the pavement.
- Longitudinal construction joints are used to control cracking that can occur due to the shrinkage of the concrete, while transverse construction joints are used to control cracking that can occur due to the expansion and contraction of the pavement due to changes in temperature.

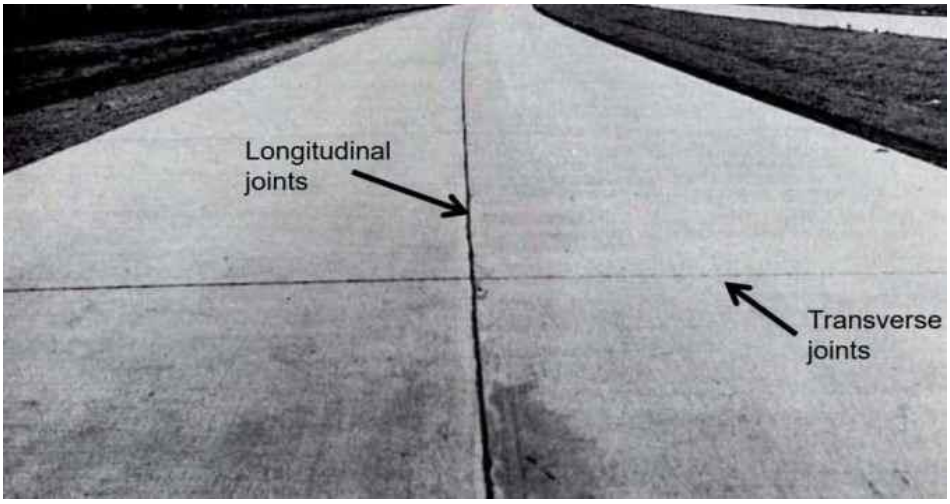


Fig1.39 Longitudinal and Transverse Joints in Pavement

4.3.1 Joints

Specific design requirements for each type depend upon the joint's orientation to the direction of the roadway (transverse or longitudinal).

There are three basic joint types used in concrete pavement:

1. Contraction
2. Construction joint
3. Isolation.
4. Expansion joints

1. Contraction Joints

Contraction joints are necessary to control natural cracking from stresses caused by concrete shrinkage, thermal contraction, and moisture or thermal gradients within the concrete. Typically transverse contraction joints are cut at a right angle to the pavement centerline and edges. Contraction joints are usually sawed into the concrete, but they might be formed or tooled on smaller projects. The details below show the different types of contraction joints and their dimensions.

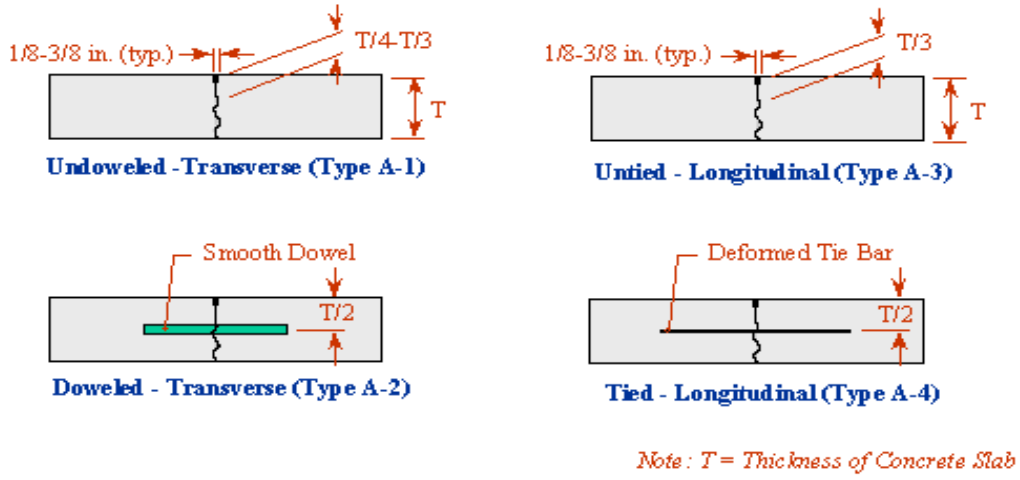


Fig1.40 Contraction joints rigid pavement

2. Construction Joints

Construction joints join concrete that is paved at different times. Transverse construction joints are necessary at the end of a paving segment or at a placement interruption for a driveway, cross road or bridge. Longitudinal construction joints join lanes that are paved at different times, or join through-lanes to curb and gutter or auxiliary lanes. The details below show the different types of construction joints and their dimensions.

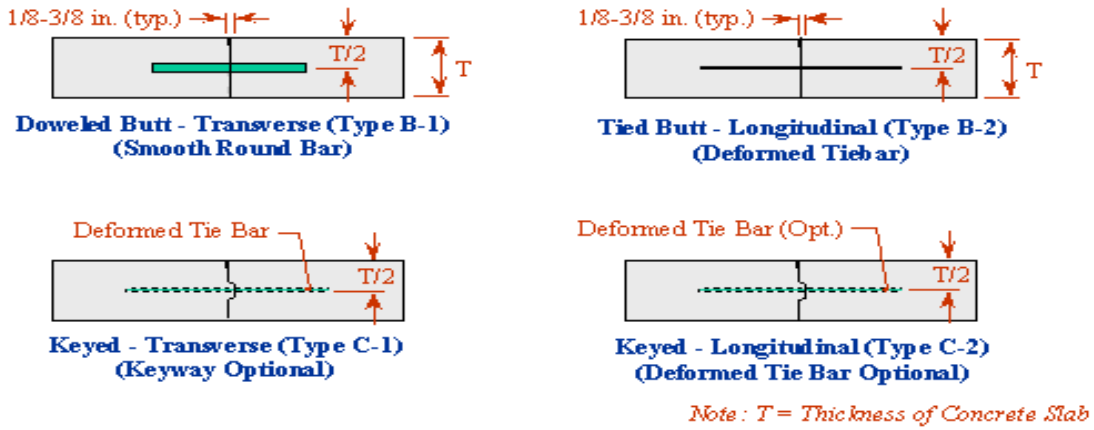


Fig1.41 joints rigid pavement

3. Isolation Joints

Isolation joints separate the pavement from objects or structures, and allow independent movement of the pavement, object or structure without any connection that could cause damage.

Isolation joints are used where a pavement abuts certain manholes, drainage fixtures, sidewalks and buildings, and intersects other pavements or bridges. The details below show the different types of isolation joints and their dimensions.

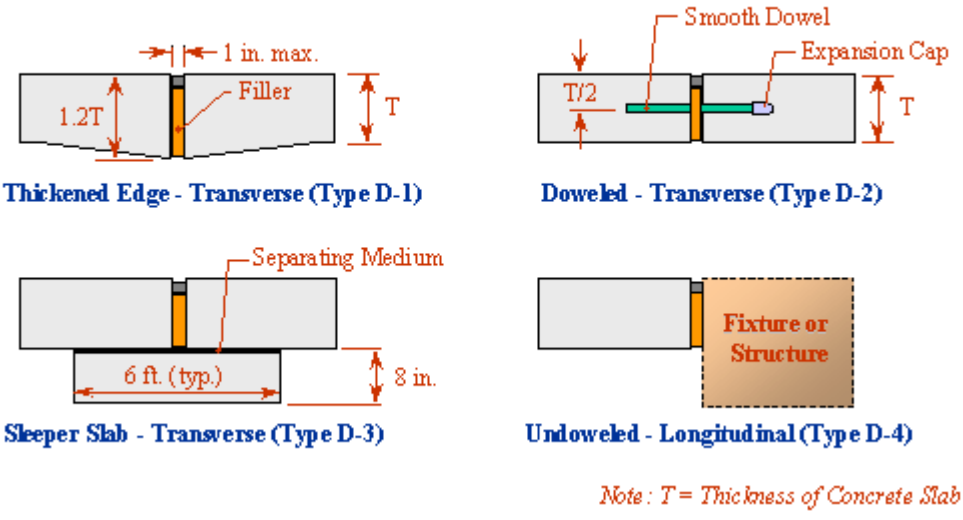


Fig1.42 Isolation joints

4. Expansion joints

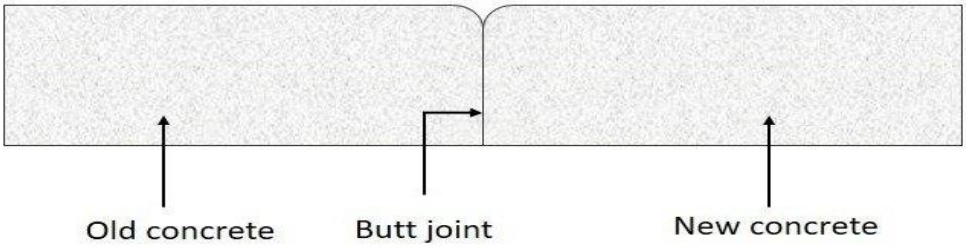
The concrete is subjected to volume change due to many reasons. So we have to cater for this by way of joint to relieve the stress. Expansion is a function of length.

Common types of joints in concrete

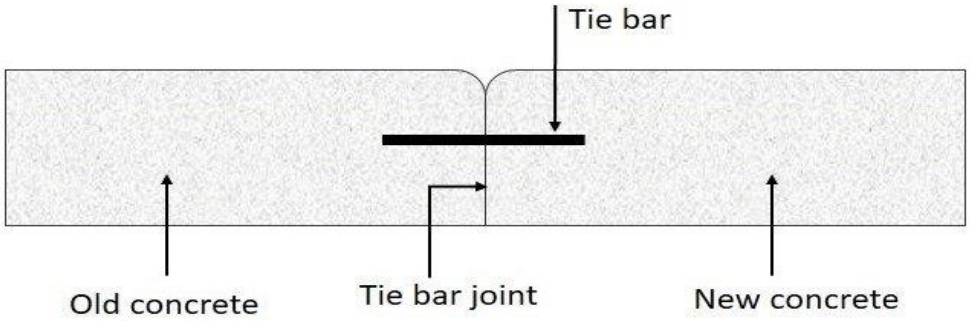
Two or more, differently aged concrete surfaces should meet in order to have the joint even

With reinforcement continuity, the separation between concrete is still valid as a construction join

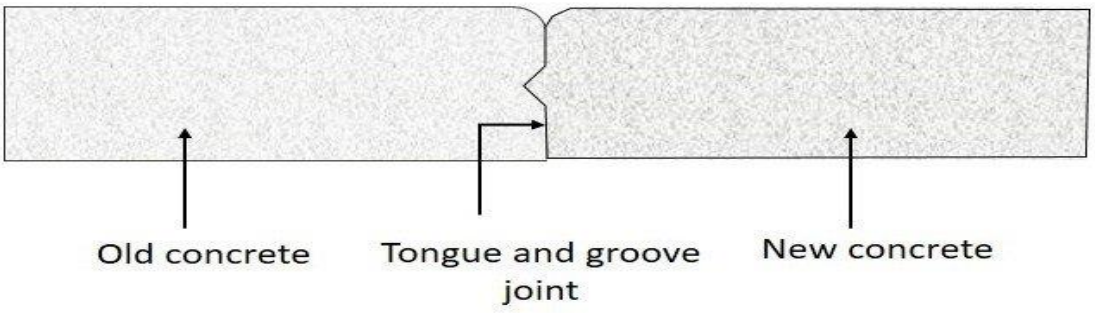
Butt joint



Tie bar joint



Tongue & groove joint



4.4 Dowel and tie Bars Joints Shape and Sealant

Dowel bars and tie bars are both used in concrete pavements to transfer loads between slabs and prevent them from cracking. The main difference between the two is that dowel bars are placed across transverse joints, while tie bars are installed across longitudinal joints.

Dowel bars are typically smooth steel bars that are inserted into the plastic concrete at the location of the joint. They are spaced at regular intervals, typically 12 to 24 inches apart. The dowel bars help to transfer the load from one slab to the next by bridging the joint.

A dowel bar is a small, round, smooth steel rod used to connect any concrete slab, column, or pavement mechanically without limiting the flexibility of the horizontal joint. These bars are primarily utilized in jointed plain concrete pavement (JPCP) to support the increased stress and load caused by a moving vehicle.

The two types of dowel bars are

- Stainless steel dowel bars
- Epoxy-coated dowel bars.

Fig1.43 Epoxy-coated dowel bars.

Fig1.41 Stainless steel dowel bars

Differences between Dowel bars and Tie bars

Table2. Difference between Dowel bars and Tie bars are as follows:

S.N	Dowel bar	Tie bar
1	It is placed around traverse joint at the mid-depth of the slab	It is placed around longitudinal joints at the mid-depth of the slab
2	The load is transfer from one slab to another and also joints are prevented from opening	Lanes are prevented from separation and differential deflection
3	They are of round, smooth, epoxy coated steel bars.	They are of deformed epoxy coated steel.
4	They can reduce joint fault and corner cracks	They can reduce transverse crack
5	Dowel bars are made up of mild steel	Tie bar are generally made up of steel
6	The diameter of the dowel bars is larger in size ranging from 30-38 mm	The diameter of the tie beam is smaller in size ranging from 10-12mm.
7	Its spacing depends only upon the thickness of the pavement. The thickness of the dowel bars varies within 300-310 mm	The spacing of the tie bars depends both upon the thickness of the pavement and the width of the slab. The thickness varies within 550-640 mm.
8	It is load transferring device from one slab to the others	It is non load transferring device.

9	While installation of the dowel bars, its main problem is it being poorly adjusted and the concrete may not be compacted properly.	While installation of the tie bars no problem of adjustment will arise.

Dowel Bar Locations

The conventional approach to dowel bar placement in new pavement construction is to place 11 bars for a 12-foot lane, starting with the first bar located 12 inches from the pavement edge, with all of the bars placed 12 inches apart from the next adjacent bar.

These bars are primarily utilized in jointed plain concrete pavement (JPCP) to support the increased stress and load caused by a moving vehicle. As d is the bar's diameter, the range of dowel bar lengths will be 45d to 50d.The two types of dowel bars are stainless steel dowel bars and epoxy-coated dowel bars.

Tie Bar Functions

1. Tie bars used for holding faces of rigid slabs in contact to keep aggregate interlock. They are also used in plain jointed concrete pavement to connect two lanes.
2. They are used to reduce transverse cracking.
3. Tie bars avoid separation and differential deflection in lanes.
4. They are not designed to work as a load transfer device.

Tie Bar Spacing

Table 2 and Table 3 are used to determine spacing of tie bars for bar diameter of 12.5mm and 16mm, respectively.

Table 3 Spacing of Tie bars for Steel Yield Strength of 280MPa and Bar Diameter of 12.5mm

Concrete Thickness, mm	**Distance to Free Edge, mm**	**Distance to Free Edge, mm**	**Distance to Free Edge, mm**	**Distance to Free Edge, mm**
-	3000	3600	4800	7200
225	650	550	400	275
250	600	500	400	250
275	550	450	350	225
300	500	400	325	225

Table 3 Spacing of Tie bars for Steel Yield Strength of 280MPa and Bar Diameter of 16mm

Concrete Thickness, mm	**Distance to Free Edge, mm**	**Distance to Free Edge, mm**	**Distance to Free Edge, mm**	**Distance to Free Edge, mm**
-	3000	3600	4800	7200
225	1050	875	650	425
250	950	775	600	400
275	850	725	525	350
300	775	650	500	325

Placement of Dowel Bars

The positioning of dowel bars involves the following steps:

1. The bars must maintain a consistent 90-degree angle with the centerline.
2. The joint or crack should have at least one-half of the dowel on each side, and a new channel must be carved for this purpose.
3. These bars are generally positioned across the concrete pavement's transverse joints as the concrete movements occur at this place.
4. They are placed near the middle of the slab and covered with a bond-forming substance to limit bonding to PCC.
5. The dowel provides assistance in transferring loads, which makes it possible for neighboring slabs to expand and contract.
6. The standard method for placing dowel bars when building new pavement is to lay 11 bars for a 3m lane commencing with the first bar placed 30cm from the pavement edge, and all subsequent bars set 30cm apart.

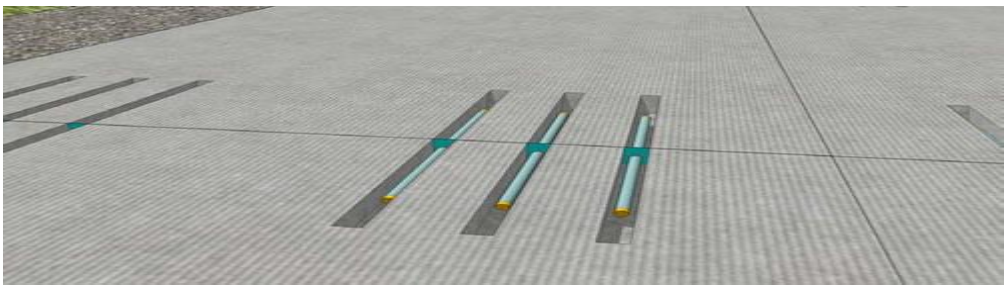


Figure1.44. Placement dowel bars

Advantages of using Dowel Bars

1. The tension and deflection are decreased by using dowel bars.
2. These bars help the slabs bear more weight by strengthening them.
3. These bars also improve the initial pavement durability.
4. Improvements in joint flexibility among the structural members.
5. It increases the project's initial cost while lowering the life cycle cost.

Disadvantages of using Dowel Bars

1. Problems arise during installation.
2. Uneven and insufficiently compacted concrete around the dowel bars.

Joints shape and sealant

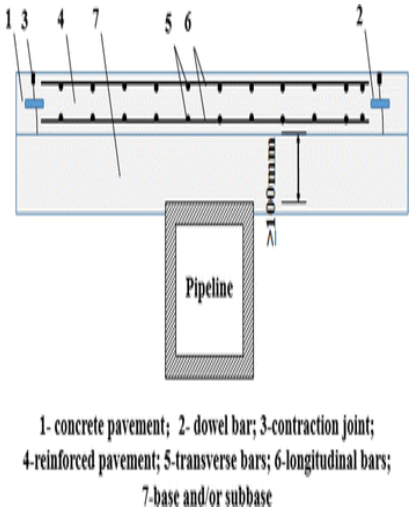
The shape of the joint between dowel bars and tie bars in concrete pavements is typically a v-shape or u-shape. This shape allows for some movement of the slabs while still providing a good surface for the sealant to adhere to. The sealant is important to prevent water and debris from entering the joint, which can damage the concrete and lead to cracking.

The type of sealant used in the joint also depends on the climate and the type of traffic. In cold climates, a flexible sealant is typically used to allow for expansion and contraction of the joint. In warm climates, a rigid sealant may be used.

Common shape for dowel and tie bar joints

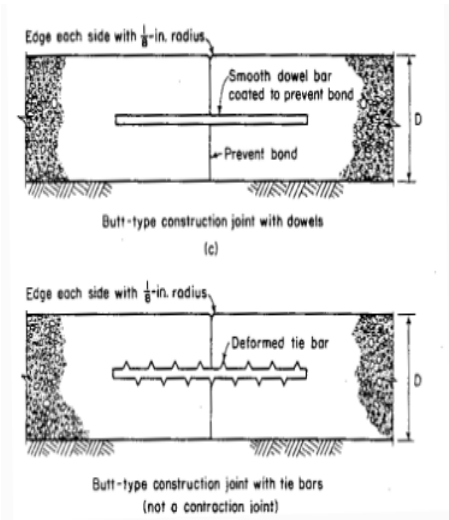
V-shaped joint: This is the most common type of joint. It is easy to construct and provides a good surface for the sealant to adhere.

U-shaped joint: This type of joint is more resistant to water infiltration than a v-shaped joint.
Rectangular joint: This type of joint is less common than v-shaped or u-shaped joints. It is typically used in areas where there is a lot of traffic, as it is more resistant to wear and tear.

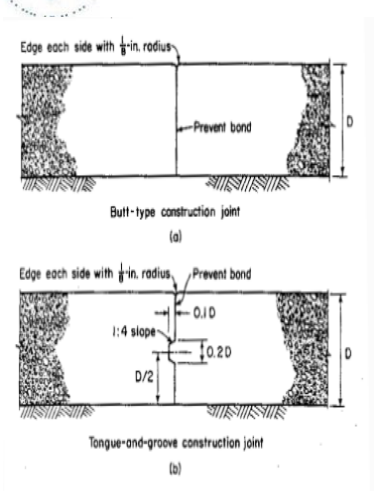


1- concrete pavement; 2- dowel bar; 3-contraction joint; 4-reinforced pavement; 5-transverse bars; 6-longitudinal bars; 7-base and/or subbase

Rectangular joint:



V-shaped joint:



U-shaped joint:

Sealant

The type of sealant used in the joint also depends on the climate and the type of traffic. In cold climates, a flexible sealant is typically used to allow for expansion and contraction of the joint. In warm climates, a rigid sealant may be used.

The following are the most common types of sealants used in dowel and tie bar joints:

- Epoxy sealants: Epoxy sealants are durable and resistant to water and chemicals. They are a good choice for high-traffic areas.
- Polyurethane sealants: Polyurethane sealants are also durable and resistant to water and chemicals. They are a good choice for areas that are exposed to sunlight.
- Silicone sealants: Silicone sealants are flexible and can accommodate a lot of movement. They are a good choice for cold climates.
- Bituminous sealants: Bituminous sealants are less expensive than other types of sealants. They are a good choice for low-traffic areas.

4.5 Spacing of tie bars and Cut material

The spacing of tie bars depends on the thickness of the concrete slab, the width of the slab, and the type of traffic that the slab will be subjected to. The following are some general guidelines for spacing tie bars:

- For slabs with a thickness of 100 mm or less, the spacing should be 500 mm to 600 mm.
- For slabs with a thickness of 100 mm to 200 mm, the spacing should be 600 mm to 700 mm.
- For slabs with a thickness of more than 200 mm, the spacing should be 700 mm to 800 mm.

The spacing of tie bars in rigid pavement typically ranges from 500 mm to 800 mm, depending on the thickness of the slab and the type of traffic that the slab will be subjected to. The cut material is the material that is removed from the slab to create the space for the tie bars. The type of cut material will depend on the type of concrete slab and the tools that are available.

Types of Cut Material

- Saw cuts: Saw cuts are made using a saw blade. They are typically used for slabs with a thickness of 100 mm or less.
- Core drills: Core drills are used to make cylindrical holes in the slab. They are typically used for slabs with a thickness of more than 100 mm.
- Wire saws: Wire saws are used to make long, thin cuts in the slab. They are typically used for slabs with a thickness of more than 200 mm.

The space of tie bars in construction joints and cut material depends on the following factors:

Diameter of the tie bars: The smaller the diameter of the tie bars, the closer they can be spaced.

Thickness of the concrete slab: The thicker the concrete slab, the closer the tie bars can be spaced.

Type of joint: The spacing of tie bars is typically closer at longitudinal joints than at transverse joints.

Design specifications: The spacing of tie bars is also specified in the design specifications for the project.

The spacing of tie bars in construction joints is typically between 12 and 24 inches (30 and 60 centimeters). The cut material is typically 6 inches (15 centimeters) wide. Wide enough to accommodate the tie bars and provide a smooth surface for the concrete to be pored over.

The tie bars are typically made of deformed steel. Type of steel the surface to bond the concrete to the tie bars. The tie bars are also typically epoxy-coated to protect them from corrosion.

Table3. Summarizes the typical spacing of tie bars for different diameters and thicknesses of concrete slabs:

Diameter of tie bars (inches)	Thickness of concrete slab (inches)	Spacing of tie bars (inches)
0.5	4	12
0.5	6	18
0.5	8	24
0.625	4	18
0.625	6	24
0.625	8	30
0.75	4	24
0.75	6	30
0.75	8	36

SELF-CHECK -4 WRITTEN TEST

TEST I: MULTIPLE CHOICE

Directions: Chose correct answer for the following Questions. Use the Answer sheet provided in the following

1. Which type of paving slab is best suited for people who like the color black and wish to keep things simple?
   A) Sandstone.
   B) Granite.
   C) Slate.
   D) Black paving slabs.
2. What is the main characteristic of slate as a natural stone?
   A) It is the second hardest natural stone after diamond.
   B) It is versatile and used for several architectural purposes worldwide.
   C) It is made up of grains.
   D) It is a metamorphic rock with a layered structure.
3. What is the maximum amount of pavement placement in one pass of a paver that requires the use of longitudinal contraction joints?
   A) 25-30 ft.
   B) 20-25 ft.
   C) 15-20 ft.
   D) 12-15 ft.
4. What is the main characteristic of slate as a natural stone?
   A) It is the second hardest natural stone after diamond.
   B) It is versatile and used for several architectural purposes worldwide.
   C) It is made up of grains.
   D) It is a metamorphic rock with a layered structure.
5. What is the purpose of contraction joints in rigid pavement?
   A) To provide load transfer.
   B) To prevent water penetration.
   C) To increase the compressive strength of pavement.
   D) To control the formation of cracks.

TEST II: TRUE OR FALSE

Direction: Direction: Write the correct answer in the blank space. Use the Answer sheet provided in the following

1._____ what is the production process of concrete paver's slabs?

2. _____Contraction joints utilize aggregate interlock as the only form of load transfer.

3._____Longitudinal contraction joints are only used when more than 15 ft of pavement is being placed in one pass.

4._____Porcelain pavers' slabs are made by heating clay and other materials at low temperatures.

5._____ Slate paving slabs are composed of grains, unlike limestone and sandstone.

TEST III: SHORT ANSWER WRITING

Instruction: write short answer for the given question. You are provided 3 minutes for each question and each point has 5 Points.

1. What is the purpose of using contraction joints in rigid pavement?
2. How far apart contraction joints are typically placed in the transverse and longitudinal direction?
3. What factors should be considered when deciding on the type of slab and load transfer mechanism for a rigid pavement project?
4. What makes limestone/marble paving slabs the finest kind of paving slabs available in the market?
5. What is the production process of concrete pavers slabs?

UNIT FIVE: Concrete Work

This learning unit is developed to provide the trainees the necessary information regarding the following content coverage and topics:

- Placing Concrete
- Checking poured concrete and finished level
- Concrete Screed Level

This unit will also assist you to attain the learning outcomes stated in the cover page.

Specifically, upon completion of this learning guide, you will be able to:

- Apply Place Concrete
- Check poured concrete and finished level
- Concrete Screed Level

5.1 Placing Concrete

Placing concrete of rigid pavement is a critical step in the construction process. the correct procedures to ensure that the pavement is durable and long-lasting. Rigid pavements are constructed; a reinforced or unreinforced in-situ concrete slab is laid over a granular sub base.

Loads are supported by the flexural strength of the pavement, which acts like a stiff plate, transferring the load over a wider area of sub grade.

Procedure for Placing Concrete

Planning for Concrete Placement

Placing concrete is the entire program consisting of equipment, layout, proposed procedures and methods is planned and placed until formwork is inspected and found suitable for placement. Equipment for conveying concrete should be of such size and design as to ensure a practically continuous flow of concrete during depositing without segregation of materials considering the size of the job and placement location.

Formwork Requirements for Concrete Placement

The formwork must be rigid so that it does not get deformed under the pressure of placement of fresh concrete and water tight so the concrete does not leak out. For every new use of formwork, the surfaces have to cleaned and brushed.

Fig1.45 formwork water tight

Concrete Placement in Special Conditions

Concrete placed in restricted forms by borrows; buggies, cars, sort chutes or hand shoveling should be subjected to the requirement for vertical delivery of limited height to avoid segregation and should be deposited as nearly as practicable in its final position.

Concrete Placement Layers

Concreting once started should be continuous until the pour is completed. Concrete should be placed in successive horizontal layers of uniform thickness ranging from 150 mm to 900 mm. The thickness of each layer should be such that it can be deposited before the previous layer has stiffened. Before placing the next concrete layer, it is necessary to properly compact the below layer. Every underlying layer will be responsive to the vibrations above.

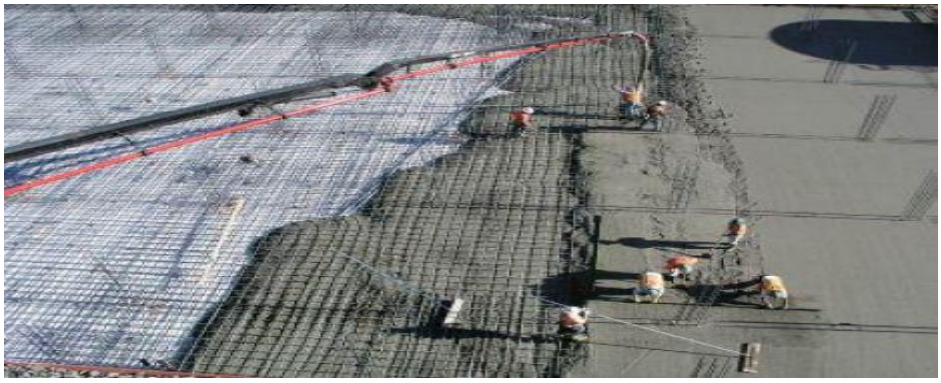


Fig 1.46 Concrete Placement Layers

Consideration for Segregation during Concrete Placement

Any tendency to segregation should be corrected by shoveling stones into mortar rather than mortar onto stones. Such a condition should be corrected by redesign of mix

Fig 1.47 Concrete Segregation

Components of Concert

Concrete is a construction material composed of

- Cement,
- Fine aggregates (sand)

- Coarse aggregates mixed with water which hardens with time.

Portland cement is the commonly used type of cement for production of concrete.

Steps of Concrete Construction

1. Selecting quantities of materials for selected mix proportion
2. Mixing
3. Checking of workability
4. Transportation
5. Pouring in formwork for casting
6. Vibrating for proper compaction
7. Removal of formwork after suitable time
8. Curing member with suitable methods and required time.

The steps of placing concrete

1. Prepare the sub grade is the surface that the concrete will be on placed. Prepare to the sub grade by leveling and compacting.
2. Install the forms are used to contain the concrete and give it the desired shape. Forms are typically made of wood or metal.
3. Place the reinforcement is used to strengthen the concrete and prevent it from cracking. Reinforcement can be made of steel bars or mesh.
4. Place the concrete is typically placed using a concrete pump. The concrete should be placed in a continuous operation and should not be allowed to set prematurely.
5. Finish the concrete is finished using a variety of tools and techniques to give it a smooth surface.
6. Cure the concrete is cured by keeping it moist for several days. This allows the concrete to reach its full strength.

5.2 Checking poured concrete and finished level

Check poured concrete and finished level of rigid pavement steps:

1. Prepare the tools and materials a level instrument, a straight edge, or a laser level, as well as a surveyor's level or transit.
2. Inspect the concrete visually inspect the concrete for any defects, such as cracks, holes, or discoloration.
3. Check the level place the level instrument, straight edge, or laser level on the concrete and check the level in both the longitudinal and transverse directions.
4. Check the elevation place the surveyor's level or transit at a known elevation and use it to check the elevation of the concrete at regular intervals.

Methods to check the poured concrete and finished level of rigid pavement:

- String line places a string line at the correct elevation and uses it to check the elevation of the concrete at regular intervals.
- Screed use a screed to check the level of the concrete as it is being poured.
- Template uses a template to check the finished level of the concrete.

5.2.1 Finishing Concrete Level

Several techniques have been developed for finishing slabs for pavements. Good finishing can provide a maintenance free surface and can offset some deficiencies of a poorly designed mix.

Types of Concrete Finishes

1. Toweled Finish

Trowel finish is the most common and popular finish of concrete used for major types of applications. After the concrete is laid in the formwork and leveled, the trowel is used to smooth and fine-level the surface of concrete.

Fig 1:48 Trowel Finished Concrete.

Trowels are available in both manual and mechanical types. A manual trowel consists of a flat steel blade with an attached handle that is pushed and pulled across the concrete surface.

A mechanized trowel is used for large commercial projects which resemble large fans with the blades sitting directly against the concrete.

2. Broom Finish

The broom finish of the concrete is rough textured finished obtained by dragging a broom on the trowel led surface of the concrete while the concrete is still fresh.

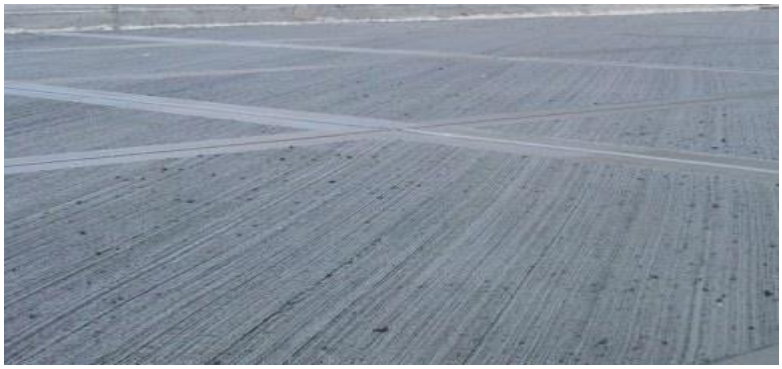


Fig 1.49: Broom Finished Concrete.

Floating -After the concrete has hardened and bleed water has disappeared, the surface is floated to a flat blade. This process compacts and removes imperfections from the surface while forcing cement and water to the surface. Excessive floating will cause a high w/c ratio and weaken the surface.

Toweling - After floating, a surface may be steel-toweled to provide a really smooth, dense, wear-resistant surface.

Texturing - If a skid-resistant surface is desired, the freshly screened surface can be textured by scoring the surface with a wire or fiber broom. Excessive paste can be removed with washing which results in an exposed aggregate finish.

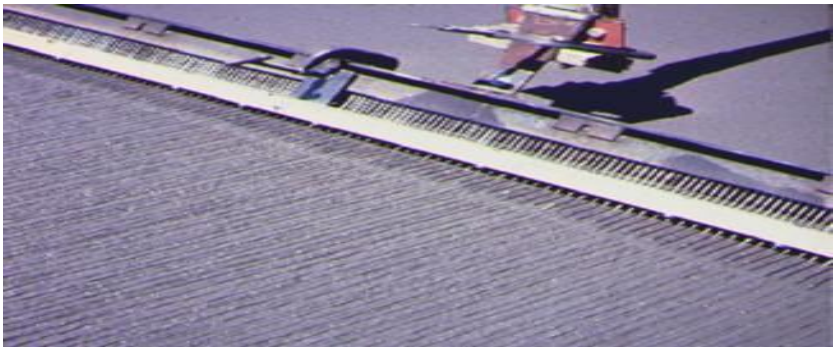


Figure1.50Tine texturing

Salt Finish

The salt finish concrete surface is obtained by inserting coarse rock salt crystals using rollers on the freshly placed concrete surface and washing it off with streams of water after the concrete is set.

Fig 1.51: Salt Finished Concrete.

This finish gives a decorative, rough subtle texture and skid resistance to plain or colored concrete. It is mainly used for swimming pools or other wet areas.

Finishing Processes

These operations are carried out by machines separate from, but often attached to and drawn by, the slip-form paver. The processes are:

1. Transverse joint forming.
2. Re-compaction and screening of the transverse joint.
3. Surface texturing, by wire brushing.
4. Application of curing agent, usually a sprayed plastic membrane.

5.3 Concrete Screed

A screening level is a specialty level that is best for landscaping and is designed for concrete work. Our special H-beam design provides superior strength. They can also be used as a check rod. Built as a level, by a level company, our screeds are not clip-on levels, but rather come with the level build directly into the tool, providing a degree of accuracy and consistency not achievable with levels clipped onto screeds.

Thickness of leveling screed

A leveling screed may be chosen for various reasons. It might be to provide a smoother, flatter surface than can be achieved economically by the structural slab. Leveling screeds are also used to provide falls or to provide a finishing zone in which different types of flooring may be accommodated.

There are several types of screed concrete:

Traditional screed: This is sand and cement mix that is applied in a semi-dry state and leveled by hand. It is commonly used in residential and commercial flooring applications.

Liquid screed: Also known as flowing screed, this type of screed is a self-leveling mix of cement, water, and additives that is poured onto a substrate and leveled by hand or machine. It is commonly used in large commercial or industrial flooring applications.

Polymer-modified screed: This type of screed is sand and cement mix that is modified with polymer additives to improve its strength and durability. It is commonly used in areas that are exposed to heavy traffic or extreme weather conditions.

Fiber-reinforced screed: This type of screed contains fibers that are added to the mix to improve its strength and durability. It is commonly used in industrial and commercial flooring applications.

Fast-drying screed: This type of screed is designed to dry quickly, often within 24 hours, making it ideal for projects that require a quick turnaround time.

Bonded screed: This type of screed is applied directly onto a base concrete slab using a bonding agent to ensure strong adhesion. It is commonly used in renovation projects where an existing concrete substrate is being covered with a new screed layer.

5.3.1 Roller Compacted Concrete for Pavement Applications

Fig1.52 roller compacted concrete

Roller Compacted Concrete is an innovative technology gaining popularity in the recent past due to some of the positive points like low cost of construction, speed in construction, and the possibility of using mineral admixtures obtained.

RCC can be used for pavement applications and this new paving method was proposed to be the best cost-effective and durable solution for rigid pavements and similar applications.

Applications

consider the limitations of the Roller Compacted Concrete; its major application is for industrial pavements such as:

- Industrial access roads
- Parking areas
- Shipping yards and port terminals
- Truck terminals
- Bulk commodity storage yards
- Aircraft Apron
- Urban streets, rural roads and parking paths
- Heavy commercial parking lots (Surface Car Parking)

Advantages

Roller Compacted Concrete Pavement (RCCP) has the following advantages when compared to the conventional pavements.

- It has high flexural and compressive strength.
- Reduction in construction time.
- Little Maintenance costs
- High freeze-thaw durability
- Reduced cracking and shrinking
- Resists abrasion even under heavy traffic loads and volume
- It has more resistance for high temperature
- More Durability and high resistance to chemical attack

Roller Compacted Concrete Pavement Construction Procedure

Rigid pavement of following types is suggested in place of flexible pavements:

- Plain Cement Concrete Pavement (PCP) with M-30, M-35 & M-40 Grade concrete
- Continuously Reinforced Concrete Pavement (CRCP)
- Roller Compacted Concrete Pavement (RCCP)

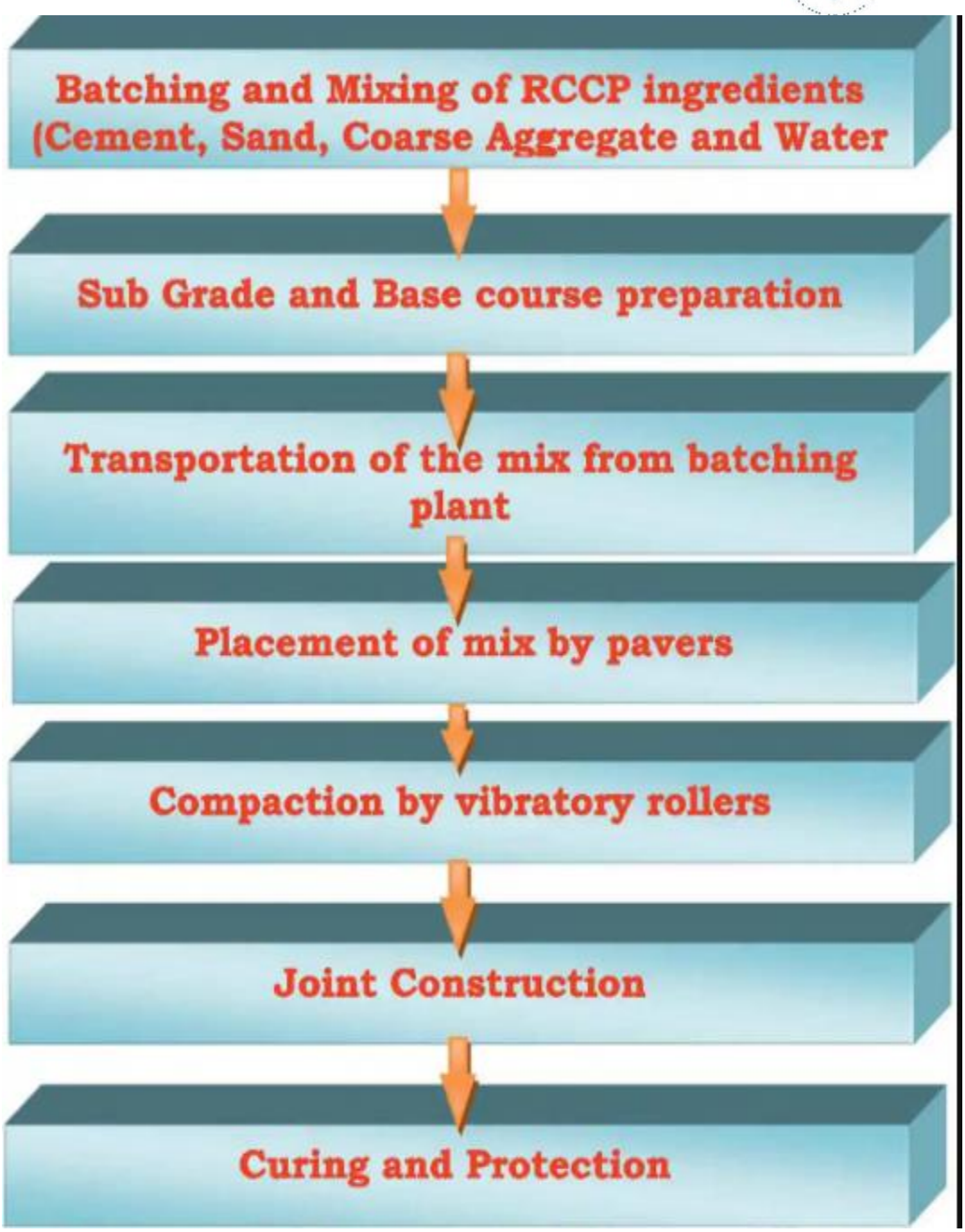


Fig1.53. Roller Compacted Concrete Pavement

Table4: Some features of Rigid Pavements	
type of Rigid Pavement	**Features**
PCP	More number of joints and it causes inconvenient to the road user.
CRCP	Reduces the need of expansion and contraction joint and thus improves riding quality and reduces the maintenance cost. Construction is difficult. More costly and involves more man power.
RCCP	Overcomes the problems of traditional pavements. Much quicker to construct. Similar kind of ingredients as that of PCP. Higher percentage of Fine aggregate allows tight packing and consolidation.

Rigid pavements consist of a number of joints, which reduces stresses caused due to temperature changes and this is a principal cause for inconvenience to the road users.

Continuously reinforced concrete pavement which reduces the need of expansion, Contraction joints and thus improves riding quality and reduces the maintenance cost compared to plain cement concrete pavement (PCP).

For the construction of conventional Continuously Reinforced Concrete Pavement (CRCP), percentage of steel required is 0.7-1.0%. Provision of steel reinforcement is important to arrest the cracks that occur in the concrete.

Compared to flexible asphalt pavements construction, the process of construction of reinforced concrete pavements is difficult and costlier and involves more manpower.

5.4 Clean Up

Cleaning Pavement

To clean pavement, follow these steps:

1. Mix your cleaning solution in a bucket
2. Spread your cleaner across the surface of your pavement
3. Scrub hard on stains, mold, and in the cracks
4. Clean the entire surface of the pavement in this way
5. Rinse off the driveway with the hose, using it to direct the runoff into a collection bucket
6. Repeat the process as needed to break apart stains

Formwork removing

Ensured that the concrete in the structural members has gained sufficient strength to withstand the design load, only then formworks should be removed. The formworks should be left for longer time as it helps in curing.

Removal of formwork from the concrete section should not make the structural element to:

- Collapse under self-load or under design load
- deflect the structural member excessively in short or the long term
- Physically damage the structural member when formwork is removed.
- Filling the Joint
- Once the joints are cleaned out completely, it’s time to refill them. We use a urethane joint compound that can flex as it dries to create a strong, permanent bond between the two slabs. Thoroughly mix the joint filler using the manufacturer’s direction, and then pour some into a smaller container for increased control and precision.
- Pour the compound filler directly into the joint, taking slow passes, allowing time for the filler to sink all the way into the void and ensure the compound reaches the top. Don’t worry about over flow; it’s more important to make sure the joint is 100 percent filled with compound.

SELF-CHECK - 5 WRITTEN TEST

TEST I: MULTIPLE CHOICE

Directions: Chose correct answer for the following Questions. Use the Answer sheet provided in the following

1. What is the advantage of the H-beam design in a screening level?
   A) It provides a smoother surface
   B) It is cheaper to produce
   C) It provides superior strength
   D) It is lighter in weight
2. What is the basic ingredient in concrete?
   A) Water
   B) Cement
   C) Sand
   D) Gravel
3. What is the purpose of a leveling screed?
   A) To provide insulation
   B) To create falls
   C) To provide a decorative finish
   D) All of the above
4. What are the remaining steps in fixed form pavement construction after laying the concrete slab?
   A) Curing, mixing, and finishing
   B) Placing, mixing, and curing
   C) Placement, finishing, and curing
   D) Vibrating, screening, and finishing
5. What is the most common type of concrete pavement construction?
   A) Fixed-form work
   B) Reinforced concrete pouring
   C) Slip form paving machine
   D) Damp sand casting

TEST II: TRUE OR FALSE

Direction: Write the correct answer in the blank space.

1. _____ a leveling screed can be used to make a surface smoother and flatter than a structural slab.
2. _____ Bonded screed is applied directly onto a base concrete slab with no bonding agent required.
3. _____ Fixed-form work is the most common type of concrete pavement construction.
4. _____ Fast-drying screed is not appropriate for projects that require a quick turnaround time.
5. _____ Polymer-modified screed contains fibers that are added to improve its strength and durability.

TEST III: SHORT ANSWER WRITING

Instruction: write short answer for the given question. You are provided 3 minutes for each question and each point has 5 Points.

1. What is a screening level in the context of concrete work and what is it used for?
2. What advantages does a level built into the screening tool provide over clip-on levels?
3. What are the benefits of using fiber-reinforced screed?
4. What types of additives are used in polymer-modified screeds and what benefits do they provide?
5. What is a fast-drying screed and what projects is it best suited for?

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