SRI KRISHNA INSTITUTE OF TECHNOLOGY

(Accredited by NAAC, Approved by A.I.C.T.E. New Delhi, Recognised by Govt. of Karnataka & Affiliated to V.T U., Belagavi)
#57, Chimney Hills, Hesaraghatta Main Road, Chikkabanavara Post, Bengaluru- 560090

IA –01

Dept:	CV	Sem / Div:	6th	Course:	Design & Construction of Highway Pavements	Elective:	Y
Date:		Time:		C Code:	BCV613D	Max Marks:	50

Note: Answer any two full questions, choosing one question from each part. Each question carry 25 marks.

QNo		Questions	CO	Level	Marks	Module
1	a	Explain the **role of subgrade soil in pavement performance.**	01	02	10	01
	b	Describe the **engineering properties of subgrade soil** required for a stable pavement.	02	02	10	01
	c	Define **flexible pavement** and list its main components	01	02	05	03
OR						
2	a	Explain the **importance of soil compaction in highway construction**.	01	03	10	01
	b	Describe the **functions of subgrade, sub-base, base course, and surface course** in a pavement system.	02	03	10	01
	c	List and explain the **factors affecting the design of flexible pavements.**	02	02	05	03
3	a	Explain the **desirable properties of bituminous binders used in flexible pavements**	01	02	10	02
	b	Describe the **combined flakiness and elongation index test** and explain its significance in aggregate shape evaluation.	03	03	10	02
	c	Explain the **concept of Equivalent Standard Axle Load (ESAL).**	02	03	05	03
OR						
4	a	Explain the **desirable properties of cement used in pavement construction**.	01	02	10	02
	b	Describe the **ductility test of bitumen** and explain how it reflects binder flexibility.	03	03	10	02
	c	Write a short note on the **IRC guidelines for flexible pavement design.**	02	02	05	03

Prepared by | Checked by | Approved

Certificate

I hereby certify that, I have completed the specified syllabus for the IA exam. I have referred the specified Text & Reference books / I have referred additional books and notes. Questions are set to cover the Course Outcomes and Blooms learning levels specified for the IA.

Faculty HoD

Name : Mr. Manjunath V

Signature :

Prepared by Checked by Approved

CIE 1– Solution

Dept:	CV	Sem / Div:	6th	Course:	Design & Construction of Highway Pavements	Elective:	Y
Date:		Time:		C Code:	BCV613D	Max Marks:	50

Note: Answer any two full questions, choosing one question from each part. Each question carry 25 marks.

QNo		Questions	CO	Level	Marks	Module
1	a	The **subgrade soil** is the natural soil prepared and compacted to form the foundation of a pavement structure. It plays a critical role in pavement performance because it supports all the loads transmitted through the pavement layers from traffic. **Roles of Subgrade Soil in Pavement Performance** 1. **Provides Structural Support** ○ The subgrade acts as the base foundation for the entire pavement system. ○ It distributes and supports loads transferred from the surface, base, and sub-base layers. ○ A strong subgrade reduces stresses in the upper pavement layers. 2. **Influences Pavement Thickness** ○ The strength of the subgrade determines the required thickness of pavement layers. ○ Weak subgrade soils require thicker pavement sections to safely distribute loads. ○ Strong subgrades allow thinner and more economical pavement designs. 3. **Controls Pavement Deformation** ○ Excessive compression or settlement of subgrade soil can cause rutting, cracking, and uneven pavement surfaces. ○ Adequately compacted subgrade minimizes permanent deformation. 4. **Affects Pavement Durability** ○ Poor-quality subgrade can lead to premature pavement failure. ○ Good subgrade strength and stability increase pavement service life and reduce maintenance costs. 5. **Influences Drainage and Moisture Behavior** ○ Changes in moisture content can significantly alter subgrade strength. ○ Water infiltration may soften the soil, reducing its load-bearing capacity. ○ Proper drainage systems help maintain subgrade stability. 6. **Provides Uniform Support** ○ Uniform subgrade conditions prevent differential settlement. ○ Non-uniform support can cause localized failures, cracks, and surface irregularities.	01	02	10 5 5	01

Prepared by | Checked by | Approved

	b	Engineering Properties of Subgrade Soil **1. Strength** • The subgrade should have sufficient **shear strength** to withstand traffic loads without failure. • Higher strength reduces the required pavement thickness. • Strength is commonly evaluated using **CBR (California Bearing Ratio)**, plate load tests, or resilient modulus. **2. Stability** • The soil should remain stable under varying traffic and environmental conditions. • It should resist displacement, rutting, and excessive deformation under repeated wheel loads. **3. Compressibility** • Low compressibility is desirable to minimize settlement. • Excessive compression can cause uneven pavement surfaces, cracks, and structural failures. **4. Compaction Characteristics** • The soil should achieve high density through compaction. • Proper compaction increases strength, reduces permeability, and improves load-bearing capacity. • Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) are important parameters. **5. Moisture Sensitivity** • The subgrade should not experience significant loss of strength when moisture content changes. • Highly moisture-sensitive soils, such as certain clays, can weaken considerably when wet. **6. Permeability and Drainage** • Adequate drainage characteristics help prevent water accumulation. • Excessive water in the subgrade reduces strength and may cause pumping, swelling, or softening. **7. Volume Stability** • The soil should undergo minimal expansion and contraction due to moisture variations. • Expansive soils can cause pavement heaving and cracking. • Shrink-swell behavior should be low. **8. Durability** • The soil should maintain its engineering properties over time despite repeated loading and weather changes. • Durable subgrades contribute to longer pavement life. **9. Resilient Modulus** • This property measures the elastic response of soil under repeated traffic loads. • Higher resilient modulus values indicate better load distribution and pavement performance. **10. Uniformity** • The subgrade should provide uniform support throughout the pavement length and width.	02	02	10 5 5	01

Prepared by　　Checked by　　Approved

		• Variations in soil properties can lead to differential settlement and localized pavement distress.				
	c	**Definition:** A **flexible pavement** is a type of pavement that consists of several layers of materials with the highest-quality material on the surface and lower-quality materials in the underlying layers. It distributes wheel loads gradually to the subgrade through load transfer between layers. Flexible pavements are generally surfaced with bituminous (asphalt) materials. **Main Components of Flexible Pavement** 1. **Surface Course (Wearing Course)** o Top layer made of bituminous concrete or asphalt. o Provides a smooth riding surface and resists traffic wear. 2. **Binder Course** o Intermediate bituminous layer between the surface course and base course. o Distributes traffic loads and provides additional strength. 3. **Base Course** o Layer of crushed stone, gravel, or stabilized material. o Transfers loads from the upper layers to the sub-base. 4. **Sub-base Course** o Layer below the base course made of granular material. o Provides drainage, additional load distribution, and protection to the subgrade. 5. **Subgrade** o Compacted natural soil forming the foundation of the pavement. o Supports the entire pavement structure and traffic loads.	01	02	05 2.5 2.5	03
2	a	**Importance:** 1. **Increases Soil Strength** o Compaction improves the load-bearing capacity of the soil. o It enables the subgrade to safely support traffic loads. 2. **Reduces Settlement** o Well-compacted soil undergoes less compression under loads. o This prevents uneven settlement and pavement deformation. 3. **Improves Stability** o Compacted soil is more resistant to shear failure and rutting. o It provides a stable foundation for pavement layers. 4. **Decreases Permeability** o Reduction of air voids limits water infiltration. o This helps maintain soil strength and prevents moisture-related damage. 5. **Reduces Shrinkage and Swelling** o Proper compaction minimizes volume changes caused by moisture fluctuations. o This reduces cracking and heaving of pavements. 6. **Increases Durability of Pavement** o A strong and stable subgrade extends pavement life. o Maintenance and repair costs are reduced. 7. **Improves Resistance to Erosion**	01	03	10 5 5	01

Prepared by Checked by Approved

		○ Compacted soils are less susceptible to erosion by water and traffic action.				
	b	**1. Subgrade** The **subgrade** is the compacted natural soil that forms the foundation of the pavement. **Functions:** • Supports the entire pavement structure. • Carries and distributes loads transmitted from upper layers. • Provides a stable and uniform foundation. • Influences pavement thickness and performance. • Prevents excessive settlement when properly compacted. **2. Sub-base Course** The **sub-base** is the layer placed between the base course and subgrade. **Functions:** • Provides additional load distribution. • Improves drainage and prevents water accumulation. • Protects the subgrade from damage due to traffic and moisture. • Reduces frost action and pumping in the pavement. • Acts as a working platform during construction. **3. Base Course** The **base course** is the main structural layer of the pavement. **Functions:** • Distributes wheel loads to the sub-base and subgrade. • Provides strength and stiffness to the pavement. • Resists deformation and rutting under traffic. • Improves the overall load-carrying capacity of the pavement. • Supports the surface course. **4. Surface Course (Wearing Course)** The **surface course** is the topmost layer directly exposed to traffic and weather. **Functions:** • Provides a smooth, safe, and comfortable riding surface. • Resists wear, abrasion, and traffic stresses. • Prevents water from entering the underlying layers. • Provides skid resistance for vehicle safety. • Enhances the appearance and durability of the pavement.	02	03	10 3 3 2 2	01

	c	• **Traffic Load**
		  • Type, volume, and axle loads of vehicles determine pavement thickness.
		  • Higher traffic requires stronger pavements.
		• **Subgrade Soil Strength**
		  • The bearing capacity of the subgrade affects the pavement design.
		  • Weak soils require thicker pavement layers.
		• **Climatic Conditions**
		  • Temperature, rainfall, and moisture influence pavement performance.
		  • Excessive moisture can weaken the subgrade.
		• **Drainage Conditions**
		  • Proper drainage prevents water accumulation in pavement layers.
			02	02	05
					2.5
					2.5
						03

Prepared by Checked by Approved

		• Good drainage increases pavement life and stability.
		• **Material Quality**
		  • Strength and durability of materials used in surface, base, and sub-base layers affect pavement performance.
		  • Better materials provide longer service life.				

3	a	Bituminous binders used in flexible pavements should possess the following properties:
		
		1. **Adhesion**
		  o Should bind strongly with aggregate particles.
		  o Prevents stripping of bitumen from aggregates in the presence of water.
		2. **Cohesion**
		  o Should have sufficient internal strength to hold aggregates together.
		  o Helps resist traffic stresses.
		3. **Durability**
		  o Should resist weathering, oxidation, and aging.
		  o Maintains its properties over a long service life.
		4. **Flexibility**
		  o Should accommodate slight pavement deformations without cracking.
		  o Prevents cracking due to temperature changes and traffic loads.
		5. **Water Resistance**
		  o Should be impermeable and resist the harmful effects of water.
		  o Protects the pavement layers from moisture damage.
		6. **Workability**
		  o Should be easy to mix, spread, and compact during construction.
		  o Ensures proper pavement laying.
		7. **Temperature Susceptibility**
		  o Should not become too soft in hot weather or too brittle in cold weather.
		o Maintains adequate consistency under varying temperatures.
			01	02	10
					
					5
					
					5
						02

	b	**Definition** The **Combined Flakiness and Elongation Index Test** is used to determine the percentage of aggregate particles that are **flaky** (thin) and **elongated** (long) in a sample. It helps assess the suitability of aggregates for pavement and concrete works. **Procedure** 1. Separate the aggregate sample into different size fractions using sieves. 2. **Flakiness Test:** o Pass each particle through the appropriate slot of the thickness gauge. o Particles with thickness less than **0.6 times** their mean size are classified as flaky. 3. **Elongation Test:** o Pass the remaining particles through the length gauge. o Particles with length greater than **1.8 times** their mean size are classified as elongated.	03	03	10 5	02

Prepared by Checked by Approved

		4. Determine the weight of flaky and elongated particles. 5. Calculate: $\text{Flakiness Index (FI)} = \frac{\text{Weight of flaky particles}}{\text{Total sample weight}} \times 100$ $\text{Elongation Index (EI)} = \frac{\text{Weight of elongated particles}}{\text{Total sample weight}} \times 100$ $\text{Combined Index} = \text{FI} + \text{EI}$ **Significance** • Indicates the **shape characteristics** of aggregates. • Flaky and elongated particles are weak and tend to break under load. • Excessive flaky and elongated particles reduce the strength and durability of pavements. • Aggregates with lower combined index provide better interlocking, stability, and load distribution. • Helps in selecting suitable aggregates for road and pavement construction.			5	
	c	**Definition:** The **Equivalent Standard Axle Load (ESAL)** is the number of repetitions of a standard axle load that would cause the same amount of pavement damage as a given axle load. It is used in pavement design to convert mixed traffic loads into an equivalent number of standard axle load repetitions. **Standard Axle Load** • The standard axle load commonly used in highway engineering is **80 kN (8.16 tonnes)** with dual wheels. **Concept** • Different axle loads cause different levels of pavement damage. • Heavier axle loads produce much greater damage than lighter loads. • ESAL converts all axle loads into an equivalent number of standard axle loads for design purposes. **Significance** 1. Helps estimate the cumulative traffic loading on a pavement. 2. Provides a common basis for comparing different axle loads. 3. Used in determining pavement thickness and structural design. 4. Assists in predicting pavement life and performance. **Example** If one heavy axle causes the same damage as **5 standard axle loads**, then: **1 heavy axle = 5 ESALs**	02	03	05 2.5 2.5	03

Prepared by | Checked by | Approved

4	a	**1. High Strength** • Cement should develop high compressive and flexural strength. • It should withstand heavy wheel loads and traffic stresses. • High-strength cement increases pavement life. **2. Good Workability** • Cement should produce concrete that is easy to mix, transport, place, and finish. • Good workability ensures proper compaction and uniformity of concrete. **3. Proper Setting Time** • The **initial setting time** should be sufficient for mixing, transportation, and laying operations. • The **final setting time** should allow the concrete to gain strength within a reasonable period. **4. Soundness** • Cement should not undergo excessive expansion after setting. • Unsound cement may cause cracks, warping, and pavement failure. **5. Durability** • Cement should resist weathering, abrasion, moisture, and chemical attacks. • Durable cement ensures long service life with minimum maintenance. **6. Low Heat of Hydration** • Excessive heat generated during hydration can cause thermal stresses and cracking. • Cement with moderate heat generation is preferred for pavement slabs. **7. Good Bonding with Aggregates** • Cement should provide strong adhesion between aggregate particles. • Good bonding improves the strength and stability of concrete. **8. Low Shrinkage** • Cement should exhibit minimum shrinkage during setting and hardening. • Reduced shrinkage minimizes cracking in concrete pavements. **9. Impermeability** • Cement concrete should be dense and resistant to water penetration. • Low permeability protects the pavement from moisture-related deterioration. **10. Resistance to Environmental Effects** • Cement should resist frost action, temperature variations, and chemical attacks from soil and groundwater. • This improves pavement performance under different environmental conditions.	01	02	10 5 5	02
	b	**Definition** The **ductility test** is conducted to determine the ability of bitumen to undergo deformation or stretching without breaking. It measures the distance to which a standard briquette of bitumen can be elongated before it breaks. **Objective** • To assess the **flexibility and adhesive properties** of bitumen. • To determine its suitability for use in road construction. **Apparatus** • Ductility testing machine • Standard briquette mould • Water bath maintained at **27 ± 0.5°C**	03	03	10 5	02

Prepared by Checked by Approved

		• Thermometer and measuring scale **Procedure** 1. Heat the bitumen sample and pour it into a standard briquette mould. 2. Allow the sample to cool and solidify. 3. Remove the mould and place the briquette in a water bath at **27°C** for about 90 minutes. 4. Fix the specimen in the ductility testing machine. 5. Pull the two ends of the briquette apart at a uniform rate of **50 mm/min**. 6. Measure the distance (in cm) at which the bitumen thread breaks. **Result** Ductility Value=Distance stretched before breaking (cm)\text{Ductility Value} = \text{Distance stretched before breaking (cm)}Ductility Value=Distance stretched before breaking (cm) **Significance in Reflecting Binder Flexibility** 1. **Indicates Flexibility** ○ Higher ductility values indicate greater flexibility of the bitumen. 2. **Resistance to Cracking** ○ Ductile bitumen can accommodate pavement deformations and temperature stresses without cracking. 3. **Durability of Pavement** ○ Flexible binders improve pavement life by reducing crack formation. 4. **Adhesion Characteristics** ○ Good ductility is generally associated with better adhesive and cohesive properties. 5. **Quality Assessment** ○ Helps in selecting suitable bitumen grades for different climatic and traffic conditions. **Interpretation** • **High Ductility (>75 cm):** Good-quality, flexible bitumen suitable for pavements. • **Low Ductility:** Bitumen is brittle and more susceptible to cracking under traffic and temperature variations.			5	
	c	The **Indian Roads Congress (IRC)** provides guidelines for the design of flexible pavements in India through **IRC: 37**. These guidelines help engineers design pavements that can safely carry anticipated traffic loads during their design life. **Key Features of IRC Guidelines** 1. **Traffic Assessment** ○ Pavement design is based on cumulative traffic loading expressed in **Million Standard Axles (MSA)**. 2. **Subgrade Strength** ○ The strength of the subgrade is evaluated using the **California Bearing Ratio (CBR)** test. ○ Pavement thickness increases as CBR value decreases. 3. **Design Life** ○ Pavements are designed for a specific service period, usually **15–20 years**, depending on road category. 4. **Layered Pavement Concept** ○ The pavement consists of **surface course, base course, sub-base, and subgrade**.	02	02	05 2.5	03

Prepared by Checked by Approved

		○ Thickness of each layer is determined based on traffic and soil conditions. 5. **Drainage and Material Considerations** ○ Proper drainage and quality materials are emphasized to improve pavement performance and durability.			2.5	

Certificate

I hereby certify that, I have referred the specified Text & Reference books / I have referred additional books and notes.

Faculty HoD

Name : Mr. Manjunath V

Signature :

Prepared by Checked by Approved