GATE 2026 Civil Engineering Question Paper with Solutions

Time Allowed :3 Hours	Maximum Marks :100	Total Questions :65

General Instructions

Read the following instructions very carefully and strictly follow them:

1. Each GATE 2024 paper consists of a total of 100 marks. The examination is divided into two sections – General Aptitude (GA) and the Candidate's Selected Subjects. General Aptitude carries 15 marks, while the remaining 85 marks are dedicated to the candidate's chosen test paper syllabus.
2. GATE 2024 will be conducted in English as a Computer Based Test (CBT) at select centres in select cities. The duration of the examination is 3 hours.
3. MCQs carry 1 mark or 2 marks.
4. For a wrong answer in a 1-mark MCQ, 1/3 mark is deducted.
5. For a wrong answer in a 2-mark MCQ, 2/3 mark is deducted.
6. No negative marking for wrong answers in MSQ or NAT questions.

1. Consider a soil sample where the following parameters are defined:

- S = **Soil suction head**
- K = **Hydraulic conductivity**
- w = **Moisture content**

If the moisture content (w) of the soil increases, which of the following statements regarding the soil suction head (S) and hydraulic conductivity (K) is correct?

(A) Both S and K increase.
(B) Both S and K decrease.
(C) S increases while K decreases.
(D) S decreases while K increases.

Correct Answer: (D) S decreases while K increases.

Solution:

Step 1: Understanding the Question:
The question asks to determine the effect of increasing moisture content (w) on two soil properties: soil suction head (S) and hydraulic conductivity (K).

Step 2: Detailed Explanation:
Effect on Soil Suction Head (S):

Soil suction (or matric suction) represents the negative pressure potential of water in unsaturated soil. It is a measure of how tightly water molecules are held to soil particles by capillary and adsorptive forces.
- When the moisture content (w) is low (drier soil), the water is held very tightly in the smallest pores, resulting in a high soil suction head (S).
- As the moisture content (w) increases, larger pores begin to fill with water. The water is held less tightly, and the capillary forces decrease. Consequently, the soil suction head (S) decreases.

Effect on Hydraulic Conductivity (K):
Hydraulic conductivity is a measure of the ease with which water can flow through the soil pores.
- In a soil with low moisture content, many pores are filled with air. These air-filled pores create discontinuous pathways for water flow, leading to very low hydraulic conductivity (K).
- As the moisture content (w) increases, more pores become filled with water. This creates more continuous and larger pathways for water to flow through the soil. As a result, the hydraulic conductivity (K) increases significantly.

Step 3: Final Answer:
Based on the explanation, as the moisture content (w) increases, the soil suction head (S) decreases, and the hydraulic conductivity (K) increases. This corresponds to option (D).

Quick Tip

Remember the inverse relationship for unsaturated soils: Wet soil = Low Suction, High Conductivity. Dry soil = High Suction, Low Conductivity. Think of a sponge: when it's dry, it 'sucks' water eagerly (high suction), but water doesn't flow through it easily (low conductivity). When it's wet, it can't suck much more water (low suction), but water passes through it readily (high conductivity).

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2. A clay deposit is found to have a natural water content and void ratio that corresponds to a pre-consolidation pressure (σ'_p) that is greater than the present effective overburden pressure (σ'_o). This clay is best classified as:

(A) OCC (Over Consolidated Clay)
(B) LCC (Lightly Consolidated Clay)
(C) NCC (Normally Consolidated Clay)
(D) Quick Clay

Correct Answer: (A) OCC (Over Consolidated Clay)

Solution:

Step 1: Understanding the Question:
The question describes a clay deposit where the maximum past effective pressure (pre-consolidation

pressure, σ'_p) is greater than the current effective pressure it is subjected to (present effective overburden pressure, σ'_o). We need to classify this type of clay.

Step 2: Detailed Explanation:
The classification of clay based on its stress history is as follows:
- **Normally Consolidated Clay (NCC):** A soil deposit that has never been subjected to an effective pressure greater than the current overburden pressure. For NCC, $\sigma'_p = \sigma'_o$. The Over Consolidation Ratio (OCR), defined as $OCR = \frac{\sigma'_p}{\sigma'_o}$, is equal to 1.
- **Over Consolidated Clay (OCC):** A soil deposit that has been subjected to a higher effective pressure in the past than its current overburden pressure. This could be due to the removal of overlying soil or glaciers, or desiccation. For OCC, $\sigma'_p > \sigma'_o$. The Over Consolidation Ratio (OCR) is greater than 1.
- **Lightly Consolidated Clay (LCC):** This is a sub-category of OCC where the OCR is slightly greater than 1, typically in the range of 1 to 4. However, it is still fundamentally an Over Consolidated Clay.
- **Quick Clay:** This is a type of highly sensitive clay that experiences a drastic loss of shear strength upon disturbance. Its classification is based on sensitivity, not directly on the relationship between past and present pressures.

Step 3: Final Answer:
The problem states that $\sigma'_p > \sigma'_o$. This is the defining characteristic of an Over Consolidated Clay (OCC). Therefore, the clay is best classified as OCC.

Quick Tip

The key to consolidation questions is the Over Consolidation Ratio (OCR). If OCR ¿ 1 ($\sigma'_p > \sigma'_o$), it's Over Consolidated. If OCR = 1 ($\sigma'_p = \sigma'_o$), it's Normally Consolidated. The clay "remembers" the maximum stress it has ever experienced.

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3. For a two-lane, two-way highway, the length of a summit curve is ideally designed based on which parameter to ensure full operational efficiency (overtaking opportunities)?

(A) Lateral friction (f)
(B) Centrifugal acceleration (a_c)
(C) Stopping Sight Distance (SSD)
(D) Overtaking Sight Distance (OSD)

Correct Answer: (D) Overtaking Sight Distance (OSD)

Solution:

Step 1: Understanding the Question:
The question asks for the ideal design parameter for the length of a summit curve on a two-lane, two-way highway, with the specific goal of ensuring "full operational efficiency," which is explicitly linked to "overtaking opportunities."

Step 2: Detailed Explanation:
Let's analyze the given parameters in the context of summit curve design:
- **Lateral friction (f) and Centrifugal acceleration (a_c):** These parameters are primarily considered in the design of horizontal curves to counteract the centrifugal force as a vehicle negotiates a bend. They are not the primary design criteria for vertical (summit) curves.
- **Stopping Sight Distance (SSD):** This is the minimum sight distance required for a driver to see an object on the roadway, react, and bring the vehicle to a safe stop. The length of any curve, including a summit curve, must *at a minimum* provide the required SSD for safety. It is a fundamental safety requirement, but not the ideal for operational efficiency.
- **Overtaking Sight Distance (OSD):** This is the minimum sight distance required for the driver of a vehicle to safely overtake another vehicle moving at a lower speed, without causing a collision with an oncoming vehicle. Providing OSD allows for overtaking maneuvers, which significantly improves the traffic flow and operational efficiency of a two-lane, two-way highway.

Step 3: Final Answer:
The question specifies the goal is "full operational efficiency (overtaking opportunities)." While SSD is a mandatory minimum for safety, the ideal design parameter to achieve this stated goal is the Overtaking Sight Distance (OSD). Therefore, the length of the summit curve should ideally be based on OSD.

> Quick Tip
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> For highway design questions, distinguish between minimum safety requirements and ideal operational standards. SSD is the absolute minimum for safety on any road section. OSD is the desirable, ideal standard for efficiency, especially on two-way roads where overtaking is critical. The keyword "ideally" or "efficiency" often points towards OSD.

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4. In a rectangular open channel, a hydraulic jump occurs. The ratio of the post-jump depth (y_2) to the pre-jump depth (y_1) is measured to be 2. What is the Froude number (Fr_1) of the flow immediately before the jump?

(A) $\sqrt{2}$
(B) 1.5
(C) $\sqrt{3}$
(D) 2.5

Correct Answer: (C) $\sqrt{3}$

Solution:

Step 1: Understanding the Question:
The question describes a hydraulic jump in a rectangular channel. We are given the ratio of the sequent depths (downstream depth y_2 to upstream depth y_1) and asked to find the Froude number of the flow before the jump (Fr_1). A hydraulic jump can only occur when the upstream flow is supercritical, i.e., $Fr_1 > 1$.

Step 2: Key Formula or Approach:
The relationship between the sequent depth ratio and the upstream Froude number for a hydraulic jump in a rectangular channel is given by the Bélanger equation:

$$\frac{y_2}{y_1} = \frac{1}{2}\left(\sqrt{1+8Fr_1^2} - 1\right)$$

Step 3: Detailed Explanation:
We are given that the ratio of post-jump depth to pre-jump depth is 2.

$$\frac{y_2}{y_1} = 2$$

Now, we substitute this value into the Bélanger equation and solve for Fr_1.

$$2 = \frac{1}{2}\left(\sqrt{1+8Fr_1^2} - 1\right)$$

Multiply both sides by 2:

$$4 = \sqrt{1+8Fr_1^2} - 1$$

Add 1 to both sides:

$$5 = \sqrt{1+8Fr_1^2}$$

Square both sides to remove the square root:

$$5^2 = 1 + 8Fr_1^2$$

$$25 = 1 + 8Fr_1^2$$

Subtract 1 from both sides:

$$24 = 8Fr_1^2$$

Divide by 8:

$$Fr_1^2 = \frac{24}{8} = 3$$

Take the square root of both sides:

$$Fr_1 = \sqrt{3}$$

Step 4: Final Answer:
The Froude number of the flow immediately before the jump (Fr_1) is $\sqrt{3}$. This corresponds to option (C).

Quick Tip

Memorize the Bélanger equation for hydraulic jumps in rectangular channels, as it's frequently tested. It directly links the upstream Froude number (Fr_1) with the ratio of depths (y_2/y_1). Knowing this formula allows for a direct and quick calculation.

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5. The Rational Method formula for estimating peak runoff is given as $Q = \frac{CiA}{360}$. For the result Q to be in cubic meters per second (m^3/s), what must be the units of rainfall intensity (i) and catchment area (A)?

(A) i in cm/hr, A in km^2
(B) i in mm/hr, A in km^2
(C) i in mm/hr, A in hectares
(D) i in m/hr, A in hectares

Correct Answer: (C) i in mm/hr, A in hectares

Solution:

Step 1: Understanding the Question:
The question requires us to perform a dimensional analysis on the Rational Method formula, $Q = \frac{CiA}{360}$. We need to find the specific units for rainfall intensity (i) and catchment area (A) that will yield the peak runoff (Q) in m^3/s, given the constant denominator of 360. The runoff coefficient (C) is a dimensionless quantity.

Step 2: Detailed Explanation:
We will analyze the units for each option to see which combination results in the correct conversion factor. The goal is to make the units on the right side of the equation equal to m^3/s.

Let's convert the units of i and A to meters and seconds for each option.

(A) i in cm/hr, A in km^2:
i in $\frac{cm}{hr} = \frac{10^{-2}\,m}{3600\,s}$
A in $km^2 = (10^3\,m)^2 = 10^6\,m^2$
$i \times A = \left(\frac{10^{-2}}{3600}\right)\frac{m}{s} \times (10^6)m^2 = \frac{10^4}{3600}\frac{m^3}{s} = \frac{1}{0.36}\frac{m^3}{s}$
So, $Q = \frac{CiA}{0.36}$. This does not match the given formula.

(B) i in mm/hr, A in km^2:
i in $\frac{mm}{hr} = \frac{10^{-3}\,m}{3600\,s}$
A in $km^2 = 10^6\,m^2$
$i \times A = \left(\frac{10^{-3}}{3600}\right)\frac{m}{s} \times (10^6)m^2 = \frac{10^3}{3600}\frac{m^3}{s} = \frac{1}{3.6}\frac{m^3}{s}$
So, $Q = \frac{CiA}{3.6}$. This is a common form of the Rational Method but does not match the formula given in the question.

(C) i in mm/hr, A in hectares:
i in $\frac{mm}{hr} = \frac{10^{-3}\,m}{3600\,s}$
A in hectares $= 10^4\,m^2$
$i \times A = \left(\frac{10^{-3}}{3600}\right)\frac{m}{s} \times (10^4)m^2 = \frac{10}{3600}\frac{m^3}{s} = \frac{1}{360}\frac{m^3}{s}$
So, $Q = C \times (i \times A) = C \times i \times A \times \frac{1}{360} = \frac{CiA}{360}$.
This perfectly matches the formula and units given in the question.

(D) i in m/hr, A in hectares:
i in $\frac{m}{hr} = \frac{1\,m}{3600\,s}$
A in hectares $= 10^4\,m^2$
$i \times A = \left(\frac{1}{3600}\right)\frac{m}{s} \times (10^4)m^2 = \frac{10000}{3600}\frac{m^3}{s} = \frac{1}{0.36}\frac{m^3}{s}$
So, $Q = \frac{CiA}{0.36}$. This does not match the given formula.

Step 3: Final Answer:
The only combination of units that satisfies the formula $Q = \frac{CiA}{360}$ for Q in m^3/s is when rainfall intensity i is in mm/hr and catchment area A is in hectares.

> **Quick Tip**
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> The Rational Method formula appears in different forms depending on the units used. The two most common forms are: 1. $Q = \frac{CiA}{360}$ for Q in m^3/s, i in mm/hr, and A in hectares. 2. $Q = \frac{CiA}{3.6}$ for Q in m^3/s, i in mm/hr, and A in km^2. Remembering these two standard forms can help you quickly solve such unit-based problems.

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6. Match the Gradually Varied Flow (GVF) profiles on a mild slope (M_1, M_2, M_3) with the nature of their water surface slope (dy/dx) relative to the flow direction. Select the correct classification:

Profile	**Nature of Slope** (dy/dx)
P. M_1 Profile	1. Positive (Rising Curve)
Q. M_2 Profile	2. Negative (Drawdown Curve)
R. M_3 Profile	3. Positive (Rising Curve)

(A) M_1 is Rising, M_2 is Rising, M_3 is Falling
(B) M_1 is Rising, M_2 is Falling, M_3 is Rising
(C) M_1 is Falling, M_2 is Rising, M_3 is Falling
(D) M_1 is Rising, M_2 is Falling, M_3 is Falling

Correct Answer: (B) M_1 is Rising, M_2 is Falling, M_3 is Rising

Solution:

Step 1: Understanding the Question:
The question asks to determine the shape of the water surface profile (rising or falling) for

the three possible Gradually Varied Flow (GVF) profiles on a mild slope: M1, M2, and M3. A rising profile has a positive slope ($dy/dx > 0$), and a falling profile has a negative slope ($dy/dx < 0$).

Step 2: Key Formula or Approach:
The governing equation for Gradually Varied Flow is:

$$\frac{dy}{dx} = \frac{S_0 - S_f}{1 - Fr^2}$$

where:

- $\frac{dy}{dx}$ is the slope of the water surface.
- S_0 is the channel bed slope (positive for a mild slope).
- S_f is the friction slope.
- Fr is the Froude number.

For a mild slope (M), the normal depth (y_n) is greater than the critical depth (y_c), i.e., $y_n > y_c$.

Step 3: Detailed Explanation:
We analyze the sign of the numerator ($S_0 - S_f$) and the denominator ($1 - Fr^2$) for each profile zone.
- Relationship between depth and slopes/Froude number: - If flow depth $y > y_n$, then $S_f < S_0$. - If flow depth $y < y_n$, then $S_f > S_0$. - If flow depth $y > y_c$, then flow is subcritical, $Fr < 1$. - If flow depth $y < y_c$, then flow is supercritical, $Fr > 1$.
M1 Profile: The flow depth y is in Zone 1, so $y > y_n > y_c$.

- $y > y_n \implies S_0 - S_f > 0$ (Numerator is positive).
- $y > y_c \implies Fr < 1 \implies 1 - Fr^2 > 0$ (Denominator is positive).
- $\frac{dy}{dx} = \frac{(+)}{(+)} = +$. The profile is **Rising**. This is a backwater curve.

M2 Profile: The flow depth y is in Zone 2, so $y_n > y > y_c$.

- $y < y_n \implies S_0 - S_f < 0$ (Numerator is negative).
- $y > y_c \implies Fr < 1 \implies 1 - Fr^2 > 0$ (Denominator is positive).
- $\frac{dy}{dx} = \frac{(-)}{(+)} = -$. The profile is **Falling**. This is a drawdown curve.

M3 Profile: The flow depth y is in Zone 3, so $y_n > y_c > y$.

- $y < y_n \implies S_0 - S_f < 0$ (Numerator is negative).
- $y < y_c \implies Fr > 1 \implies 1 - Fr^2 < 0$ (Denominator is negative).
- $\frac{dy}{dx} = \frac{(-)}{(-)} = +$. The profile is **Rising**.

Step 4: Final Answer:
Summarizing the results:

- M_1 is a Rising curve.

- M_2 is a Falling curve.
- M_3 is a Rising curve.

This matches option (B).

Quick Tip

For any GVF profile, remember this rule: The water surface always tends towards the normal depth line (y_n). If the flow is subcritical ($Fr < 1$, as in M1 and M2), this happens from upstream. If the flow is supercritical ($Fr > 1$, as in M3), this happens from downstream control. For M1 ($y > y_n$), the profile must fall to reach y_n (but it's a backwater curve, so it rises). For M2 ($y_n > y$), it falls towards y_c. For M3, it must rise to reach y_c. A more visual tip: All profiles tend towards horizontal at y_n and vertical at y_c.
