受験番号 examinee number

「社会基盤学」問題冊子

Question Booklet of "Civil Engineering"

2025年度　大学院入試 東京大学大学院工学系研究科社会基盤学専攻　修士課程

The 2025 Entrance Examination Master's program, Department of Civil Engineering, Graduate School of Engineering, The University of Tokyo

2024年8月26日（月）13:00 – 15:30（日本時間）August 26th, 2024 (Monday) 13:00 – 15:30 (in JST)

分野1 (Field 1)	構造・設計 (Structures / Design)
分野2 (Field 2)	材料 (Concrete engineering)
分野3 (Field 3)	地盤 (Geotechnical engineering)
分野4 (Field 4)	水圏工学A (Hydrospheric engineering A)
分野5 (Field 5)	水圏工学B (Hydrospheric engineering B)
分野6 (Field 6)	交通 (Transportation)
分野7 (Field 7)	空間情報 (Spatial information engineering)
分野8 (Field 8)	都市・景観 (Urban / Landscape)
分野9 (Field 9)	マネジメント (Management)
分野10 (Field 10)	国際プロジェクト (International project)
分野11 (Field 11)	数学 (Mathematics) 別冊**(Separate Booklet)**

注意事項 / Notices

- 本問題冊子表紙の右上に受験番号を記載してください。Write your examinee number at the upper right box of this page.
- 日本語もしくは英語で、解答すること。Answers must be written in Japanese or English.
- 3分野に対して解答すること。どの3分野を解答したかを解答分野申告用紙に記入すること。解答分野申告用紙での申告と異なる分野の解答は採点されません。Answer the questions in the three exam fields. Write your answered exam fields in the Declaration Form of answered exam fields. If you answer questions in exam fields different from those you selected in the form, your answers will not be scored.
- 分野ごとに、1枚ずつ解答用紙を使用してください。Please use one answer sheet for each field.
- 解答用紙は分野1-10の解答用である「社会基盤学」と書かれた用紙が3枚と、分野11の解答用である「数学」と書かれた用紙1枚の、計4枚配られる。解答分野申告用紙に記入された3分野に対応する3枚の解答用紙が採点対象となり、残る1枚は採点されない。You received three answer sheets named "Civil Engineering", which should be used to answer Field 1-10, and one answer sheet named "Mathematics", which should be used to answer Field 11. Totally you received 4 answer sheets. Three answer sheets which correspond to three fields you write in the Declaration Form of answered exam fields will be scored and the remaining sheet will not be scored.
- 分野1-10の解答にあたっては、解答用紙の所定の欄に受験番号と分野番号を記入してください。When you answer Field 1-10, please fill your examinee number and exam field number for all the answer sheets.
- 分野11(数学)は別冊になります。6問中1問を選択して解答してください。解答用紙の所定の欄に受験番号と問題番号を記入してください。 You can find problems of Field 11 (Mathematics) in the separate booklet. Please select one problem out of six problems. Please fill your examinee number and write the problem number that you answer in the boxes of the answer sheet.
- 解答に用いなかった解答用紙1枚についても受験番号を記入の上、左上の欄に「N/A」と記入すること。For an answer sheet which you did not use for answering, you must write "N/A" in the upper left box. Your examinee number should also be written.
- 解答用紙の裏面を使用しても構いません。解答用紙を追加することはできません。You can use both sides of the answer sheets. Additional answer sheets are not available.
- 試験終了時には、問題冊子および解答用紙をすべて回収します。You must return the booklets and all the answer sheets after the examination.

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分野 1/Field 1: (Structures / Design)

Consider the vibration response of a construction transport vehicle being loaded with soil of weight $m_S g$ as shown in Figure 1(A). Assume that the vehicle can be modeled as a damped linear single-degree-of-freedom system with a mass m_V, damping coefficient c_V, and spring constant k_V, as shown in Figure 1(B). Answer the following questions under the assumption that the vehicle's damping ratio $\zeta_V = c_V/(2\sqrt{m_V k_V})$ is less than 1, and m_V is significantly larger than m_S.

The definitions of mathematical symbols and variables are as follows:

- t: Time
- g: Gravitational acceleration.
- $x(t)$: Vertical displacement of the vehicle in Figure 1(B) and Figure 2 based on a stationary coordinate system. The displacement in the stationary state before loading the soil is 0.

(1) Write the vibration equation of the vehicle when the external force due to the soil is $f(t)$.

(2) Let's determine the displacement response $x(t)$ of the vehicle for $t \geq 0$ when the external force $f(t)$ is given by the following equation [1]. The displacement response $x(t)$ can be expressed as the sum of a particular solution ($x_p(t)$) of the vibration equation for forced vibration and the general solution ($x_h(t)$) of the vibration equation for free vibration when the external force is zero. Determine both $x_p(t)$ and $x_h(t)$. The undetermined constants of the general solution can be left as they are.

$$f(t) = \begin{cases} 0 & (t < 0) \\ m_S g & (t \geq 0) \end{cases} \qquad [1]$$

(3) Determine the minimum and maximum values of $x(t)$ assuming that the damping ratio of the vehicle is extremely small and can be neglected, and then sketch the graph of $x(t)$ showing the minimum and maximum values. The initial conditions are $x(0) = 0$ and $\dot{x}(0) = 0$.

Next, at time $t = 0$ right after the soil was loaded as described in equation [1], the vehicle started moving at a certain velocity on an uneven road surface, as shown in Figure 2.

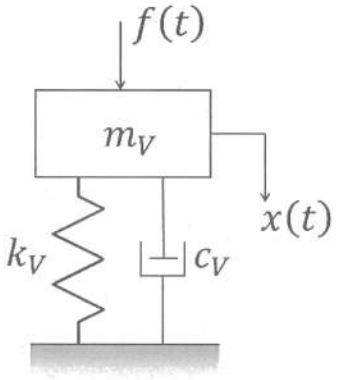
The definitions of mathematical symbols and variables are as follows:

- $y(t)$: Elevation of the uneven road surface in Figure 2 based on a stationary coordinate system.
- Y: Amplitude of the elevation of the uneven road surface in Figure 2.
- ω: Circular frequency of the uneven road surface in time.
- $\omega_n = \sqrt{k_V/m_V}$: Natural circular frequency of the vehicle.

(4) Write the vibration equation for the vehicle shown in Figure 2 assuming that $y(t)$ is given by equation [2], and then determine its particular solution.

$$y(t) = Y\sin(\omega t) \quad (t \geq 0) \qquad [2]$$

(5) At time $t = \pi/\omega_n$, determine the condition that ω/ω_n must satisfy for the displacement response $x(t)$ to be smaller than the maximum value obtained in (3). The initial conditions are $x(0) = 0$ and $\dot{x}(0) = 0$. Assume that the damping ratio of the vehicle is extremely small and can be neglected.



(A)* (B)

Figure 1. A damped linear single-degree-of-freedom system.

* Source of the photo: A. Stentz et al., "A Robotic Excavator for Autonomous Truck Loading," *Autonomous Robots*, Vol.7, No.2, pp.175-186, 1999.

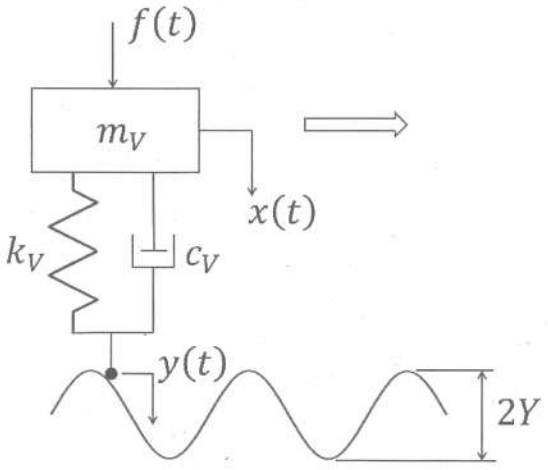


Figure 2. A damped linear single-degree-of-freedom system moving on an uneven road surface.

Construction Transport Vehicle：建設用運搬車両, A Damped Linear Single-degree-of-freedom System：減衰のある線形 1 自由度系, Mass：質量, Damping Coefficient：減衰係数, Spring Constant：ばね定数, Damping

Ratio：減衰比, m_V is significantly larger than m_S: m_Vはm_Sより十分大きい

Gravitational Acceleration：重力加速度, Vertical Displacement：鉛直方向の変位, Stationary State：静止状態, Stationary Coordinate System：静止座標系, Natural Circular Frequency：固有円振動数

Vibration Equation：振動方程式, Displacement Response：変位応答, External Force：外力, Particular Solution：特殊解(特解), Forced Vibration：強制振動, General Solution：一般解, Free Vibration：自由振動, Initial Conditions：初期条件, Undetermined Constants：未定定数

Uneven Road Surface：凹凸のある路面, Elevation：高さ

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分野 2/Field 2: (Concrete engineering)

(1) Answer the following questions.

a) Consider the section of a reinforced concrete (RC) member with materials' properties given in Figure 1. Show the calculation process when answering the questions. Do not use safety factors.

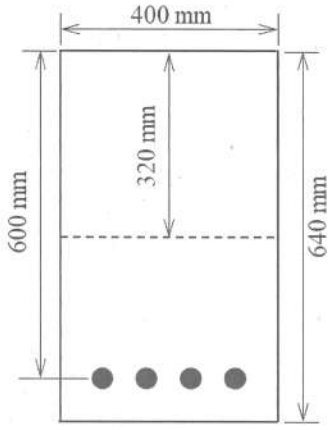
a-I) When the RC member is subjected to only flexural moment, calculate the ultimate flexural capacity (moment) at failure.

a-II) Consider a situation that 1,000,000 N of axial force is applied to center height of the section of the RC member. When the RC member is subjected to flexural moment under the situation, calculate the ultimate flexural capacity (moment) at failure.

b) Pre-stressing forces in pre-stressed concrete beams are often eccentric. Explain the reason in about 3 lines. You may use illustrations, if needed.

c) Explain the important concept in the design of RC members for toughness in ultimate state by using all the following keywords, in about 3 lines. Underline each keyword when it first appears in the answer.

Keywords: *Flexural compression failure, Shear failure, Brittle failure*



Black dot (●) indicates a reinforcing steel bar
Dotted line indicates center height of section

Total cross-sectional area of reinforcements: $A_s = 4{,}000$ mm^2
Yield strength of reinforcement: $f_y = 350$ N/mm^2
Elastic modulus of reinforcement: $E_s = 200{,}000$ N/mm^2
Compressive strength of concrete: $f'_c = 35$ N/mm^2
Ultimate compressive strain of concrete: $\varepsilon'_u = 0.0035$

Figure 1. Reinforced concrete section and material properties.

(2) Answer whether each of the following statements is TRUE or FALSE. If it is FALSE, write the reason in about 2 lines, referring to the scientific mechanisms.

a) It is important to ensure sufficient air content in hardened concrete to reduce frost damage of concrete. The sizes and spacing of the air bubbles are not important for this purpose.

b) Use of blast furnace slag powder as a cement substitution increases chloride binding of concrete, which reduces the steel corrosion resistance of RC against salt attack.

c) Use of fly ash as a cement substitution generally degrades the workability of fresh concrete.

d) Moderate-heat Portland cement is often used in high-strength concrete with low water-cement ratios and high cement content. Moderate-heat Portland cement is therefore less commonly

used in dam concrete with low cement content.

e) Honeycombs appearing in early age concrete are generally due to segregation during casting, which is caused by several factors, such as insufficient compaction and inappropriate mix proportion.

section: 断面, member: 部材, safety factor: 安全係数, flexural moment: 曲げモーメント,
ultimate flexural capacity: 曲げ耐力, axial force: 軸力, pre-stressing force: プレストレス力, beam: 梁(桁),
eccentric: 偏心, design: 設計, toughness: 靭性, flexural compression failure: 曲げ圧縮破壊,
shear failure: せん断破壊, brittle failure: 脆性破壊, reinforcing steel bars (reinforcements): 補強鉄筋,
yield strength: 降伏強度, elastic modulus: 弾性係数, compressive strength: 圧縮強度,
ultimate compressive strain: 圧縮破壊ひずみ,

sufficient: 十分な, air content: 空気量, frost damage: 凍害, spacing: 間隔, air bubble: 空気泡,
blast furnace slag powder: 高炉スラグ微粉末, cement substitution: セメント代替,
chloride binding: 塩化物固定, corrosion: 腐食, salt attack: 塩害, fly ash: フライアッシュ,
degrade: 悪化させる, workability: ワーカビリティ, fresh concrete: フレッシュコンクリート,
moderate-heat Portland cement: 中庸熱ポルトランドセメント, water-cement ratio: 水セメント比,
honeycombs: ジャンカ(豆板), segregation: 材料分離, casting: 打込み, compaction: 締固め,
mix proportion: 配合

分野 3/Field 3:(Geotechnical engineering)

(1) Answer the following questions on liquefaction phenomena of ground.

a) Explain the mechanism of liquefaction in sandy ground during an earthquake, in about 3 lines.

b) List three factors that affect the onset of liquefaction during earthquake, and explain their physical mechanism in about 3 lines in total.

(2) Answer the following questions on active earth pressure on retaining wall.

a) Explain the concept of obtaining the active earth pressure based on (i) Rankine's earth pressure theory and (ii) Coulomb's earth pressure theory, in about 4 lines in total.

b) Explain three conditions for the actual active earth pressure on the retaining wall to be equal to that obtained by Rankine's earth pressure theory.

(3) Hollow cylindrical torsional shear test is often used for evaluating the strength and deformation characteristics of soil. Explain the characteristics of the hollow cylindrical torsional shear test in about 3 lines, including its advantage and disadvantage.

(4) Excessive groundwater pumping can cause significant fall of groundwater level and ground settlement. Consider the ground shown in Figure 1. Here, GL indicates the ground level. The groundwater level is initially GL−5.0 m, then lowered to GL−10.0 m by the groundwater pumping. Estimate the ground settlement due to the effect of groundwater lowering, by answering the following questions.

Here, the settlement of the sand layer can be ignored. Degree of saturation of the sand layer above the groundwater level is S_r=50%, water density is ρ_w=1.0 g/cm^3, compression index of clay layer is C_c=0.9, and gravitational acceleration is g=10 m/s^2. If necessary, the following values can be used; $\log_{10}2=0.30$, $\log_{10}3=0.48$, $\log_{10}5=0.70$, $\log_{10}7=0.85$, $\log_{10}11=1.04$.

(a) Calculate the following three values:

- saturated unit weight of sand
- saturated unit weight of clay
- wet unit weight of sand above the groundwater level

(b) Draw a figure of the vertical distributions of pore water pressure (hydrostatic pressure), u:

- when the groundwater level is GL−5.0 m using a solid line
- when the groundwater level is GL−10.0 m using a broken line

(c) Draw a figure of the vertical distributions of vertical effective stress, σ_v':

- when the groundwater level is GL−5.0 m using a solid line
- when the groundwater level is GL−10.0 m using a broken line

(d) Calculate effective vertical stress at the middle height of the clay layer (GL−14.0 m) when the groundwater level is GL−5.0 m and GL−10.0 m, respectively.

(e) Calculate the change of void ratio in the clay layer and the approximate value of settlement, using the result of (d).

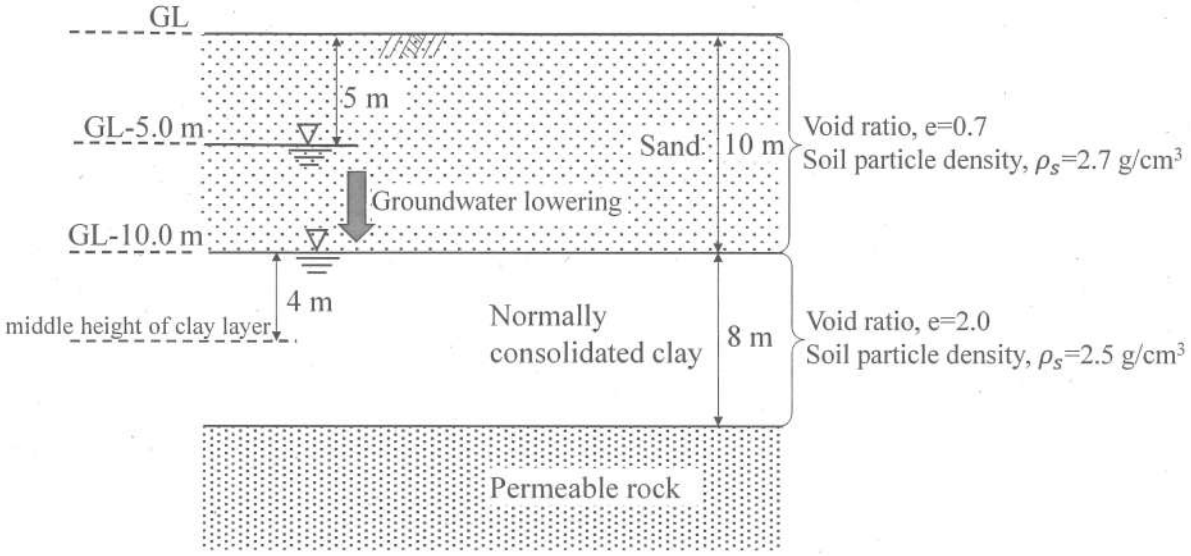


Figure 1. Ground condition and groundwater level.

onset of liquefaction:液状化の発生

active earth pressure:主働土圧, retaining wall:擁壁, Rankine's earth pressure theory:ランキンの土圧理論, Coulomb's earth pressure theory:クーロンの土圧理論, actual:実際の

hollow cylindrical torsional shear test:中空ねじりせん断試験,
strength and deformation characteristics of soil:土の強度および変形特性

excessive groundwater pumping: 過剰な地下水のくみ上げ, groundwater level:地下水位, settlement:沈下, degree of saturation:飽和度, water density:水の密度, compression index of clay layer: 粘土層の圧縮指数, gravitational acceleration:重力加速度, saturated unit weight:飽和単位体積重量,
wet unit weight:湿潤単位体積重量, vertical distribution: 深度分布, pore water pressure:間隙水圧, hydrostatic pressure:静水圧, vertical effective stress:鉛直有効応力, void ratio:間隙比,
approximate value:概略値, solid line:実線, broken line:破線, respectively: それぞれ,
soil particle density:土粒子密度, normally consolidated clay:正規圧密粘土, permeable:透水性のある

分野 4/Field 4: (Hydrospheric engineering A)

A circular-crested dam holds stationary water up to its crest level as illustrated in Figure 1. We define the x-axis as extending horizontally downstream from the upstream toe of the dam, the z-axis upward from the dam crest level and the y-axis perpendicular to both the x and z axes (see Figure 1). The dam cross-section is semicircular with radius R and uniform in the y direction. Answer the following questions. Density of water is ρ and gravitational acceleration is g. Assume atmospheric pressure to be zero.

(1) Find the resultant horizontal force of water pressure on the dam per unit length in the y direction.

(2) Find the bulk density required for the dam to remain stable against sliding. Assume a static friction coefficient of 0.5 between the dam and the ground surface.

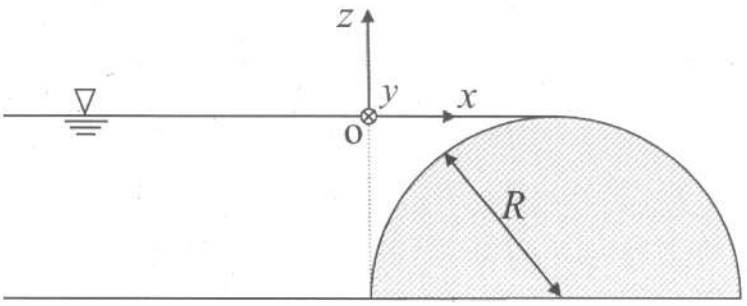


Figure 1. Cross-section of a circular-crested dam holding stationary water.

Upstream water discharge raises the water level and generates a steady state as illustrated in Figure 2. The upstream flow, away from the dam ($x < -R$), can be considered a uniform horizontal flow. The upstream flow velocity is $U = \sqrt{gR}/6$, which is assumed to be uniform throughout the depth. The water surface elevation from the dam crest level, $\eta(x)$, is approximated by the following function:

$$\frac{\eta(x)}{R} = \frac{1}{2} - \frac{1}{24}\left(\frac{x}{R}+1\right)^2 \quad \text{for} \quad -R \le x \le R. \qquad [1]$$

Answer the following questions. Neglect the flow friction on the bed including the dam surface. You may introduce additional approximations as needed, but they should be stated explicitly.

(3) Find the depth-averaged horizontal velocity above the dam crest ($x = R$) using mass conservation.

(4) Find the pressure at the upstream toe of the dam, $(x, z) = (0, -R)$, using energy conservation.

(5) The flow velocity satisfies the following kinematic condition along the water surface:

$$u\frac{d\eta}{dx} = w \quad \text{for} \quad z = \eta(x), \tag{2}$$

where u and w are horizontal and vertical velocity components, respectively. Find u and w at the water surface above the dam crest, $(x, z) = (R, \eta(R))$.

(6) Find u and w at the dam crest, $(x, z) = (R, 0)$, based on the assumption that the horizontal velocity component varies linearly with the depth above the dam crest.

(7) Draw a sketch of the vertical distribution of pressure above the dam crest ($x = R$), based on the assumption in (6).

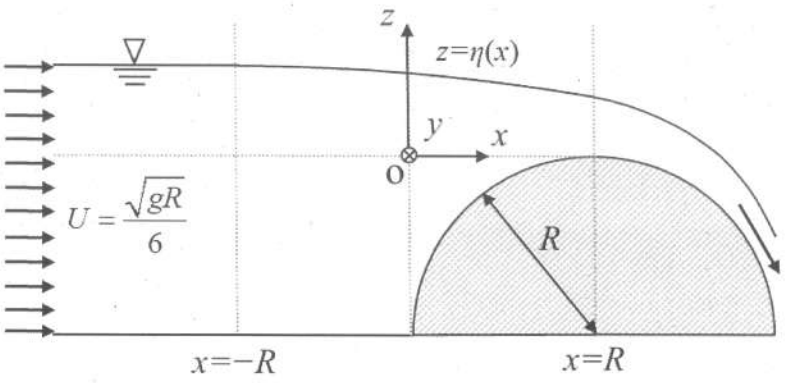


Figure 2. A steady flow over the circular-crested dam.

circular-crested dam: 円形状の頂部を有するダム, stationary water: 静止した水, crest: 頂部, upstream toe: 上流側の下端, perpendicular: 垂直な, semicircular: 半円形の, radius: 半径, density: 密度, gravitational acceleration: 重力加速度, atmospheric pressure: 大気圧, resultant horizontal force: 水平合力, bulk density: かさ密度, sliding: 滑動, static friction coefficient: 静止摩擦係数, discharge: 流量, steady state: 定常状態, uniform horizontal flow: 一様な水平流, flow friction: 流れによる摩擦, bed: 底面, approximation: 近似, depth-averaged: 水深平均の, mass conservation: 質量保存, energy conservation: エネルギー保存, velocity component: 流速成分, kinematic condition: 運動学的条件, linearly: 直線的に

分野 5/Field 5: (Hydrospheric engineering B)

(1) Regarding the following statements about climate change, answer whether each statement is TRUE or FALSE. If it is FALSE, explain the reason.

a) According to the IPCC AR6 (Intergovernmental Panel on Climate Change 6th Assessment Report), it is still difficult to conclude that the rise in global air temperature since the Industrial Revolution is certainly due to greenhouse gas emissions by humans, because there are many other factors that affect Earth's climate.

b) The Paris Agreement requires all member nations to decide targets to reduce greenhouse gas emissions, regardless of their level of responsibility for past emissions.

c) The amount of water vapor that the atmosphere can hold increases along with air temperature rise. As a result, annual mean precipitation is expected to increase in all regions of the world.

d) Compared to local-scale meteorological extremes such as heavy rainfall, river discharge reflects basin-wide-scale water circulation processes. Thus, it is relatively easy to identify the impact of climate change from long-term data on annual maximum river discharge.

(2) Countermeasures against climate change can be classified into "mitigation measures" and "adaptation measures". Answer the following questions regarding these countermeasures.

a) Write the definitions and examples of "mitigation measure" and "adaptation measure" in about 4 lines in total.

b) In the Paris Agreement, "keeping a global temperature rise this century well below 2 °C above pre-industrial levels" was decided as a globally common target for mitigation measures, while such common target was not made for adaptation measures. Explain why setting globally common target is difficult for adaptation measures in about 3 lines.

c) What are the potential benefits for developed countries to support adaptation measures in developing countries? Explain in about 3 lines, citing multiple examples of the benefits.

(3) Due to the intensification of river flooding under climate change, it is becoming difficult to avoid losses and damages by floods only through the conventional flood control measures, such as dams and levees to prevent inundation outside of river areas. Therefore, various flood risk reduction measures that go beyond conventional measures are currently being considered.

Consider several flood risk reduction measures that are effective in reducing losses and damages from large-scale flood hazards. Discuss how these measures can reduce flood risk and what difficulties are expected in implementing them, within 10 lines in total.

Use ***at least five keywords*** from the list below, and underline each when it first appears.

Keywords: Basin-wide approach, Land use, Flood forecasting, Multiple stakeholders, Green infrastructure, Co-benefit, Compensation, Reinforcement

Intergovernmental Panel on Climate Change: 気候変動に関する政府間パネル, 6th Assessment Report: 第 6 次評価報告書, Industrial Revolution: 産業革命, certainly: 間違いなく, greenhouse gas emission: 温室効果ガス排出, Paris Agreement: パリ協定, member nations: 加盟国, regardless of: 関係なく, responsibility for past emissions: 過去の排出に対する責任, water vapor: 水蒸気, atmosphere: 大気, annual mean precipitation: 年平均降水量, meteorological extreme: 極端気象現象, heavy rainfall: 豪雨, river discharge: 河川流量, basin-wide-scale: 流域規模, identify: 特定する, annual maximum: 年最大値

countermeasure: 対策, mitigation measure: 緩和策, adaptation measure: 適応策, pre-industrial: 産業革命前の, citing: 参照しつつ

intensification: 激化, losses and damages: 損失と被害, conventional flood control measure: 従来型の洪水制御対策, levee: 堤防, inundation: 氾濫, river area: 河川区域, flood risk reduction measure: 洪水リスク低減対策, implementing: 実施, underline: 下線を引く
basin-wide approach: 流域全体にわたるアプローチ, land use: 土地利用, flood forecasting: 洪水予測, multiple stakeholders: 複数の利害関係者, green infrastructure: グリーンインフラストラクチャー, co-benefit: 相互利益, compensation: 補償, reinforcement: 強化

分野 6/Field 6: (Transportation)

Consider that you have conducted a stated preference (SP) survey on transportation mode choice with three alternatives: regular vehicle (RV), private (personally owned) autonomous vehicle (PAV), and shared autonomous vehicle (SAV). Here, the SAV system is a driverless ride-hailing service. Passengers of SAVs send a request specifying pickup and drop-off points using a mobile application, and the system assigns vehicles through a matching algorithm (e.g., matching the request with the nearest vehicle).

Now you want to analyze the SP data by estimating the following discrete choice model. The utility function of individual n choosing alternative i is defined as:

$$U_{i,n} = V_{i,n} + \varepsilon_{i,n} \quad [1]$$

where $\varepsilon_{i,n}$ follows an independently and identically distributed (i.i.d.) Gumbel distribution with the location parameter being zero and the scale parameter being one, and $V_{i,n}$ are defined as follows:

$$V_{\mathrm{RV},n} = \mathrm{ASC}_{\mathrm{RV}} + \beta_{\mathrm{cost}}\mathrm{cost}_{\mathrm{RV},n} + \beta_{\mathrm{time,RV}}\mathrm{time}_{\mathrm{RV},n} \quad [2]$$

$$V_{\mathrm{PAV},n} = \mathrm{ASC}_{\mathrm{PAV}} + \beta_{\mathrm{cost}}\mathrm{cost}_{\mathrm{PAV},n} + \beta_{\mathrm{time,PAV}}\mathrm{time}_{\mathrm{PAV},n} \quad [3]$$

$$V_{\mathrm{SAV},n} = \beta_{\mathrm{cost}}\mathrm{cost}_{\mathrm{SAV},n} + \beta_{\mathrm{time,SAV}}\mathrm{time}_{\mathrm{SAV},n} + \beta_{\mathrm{wait}}\mathrm{wait}_{\mathrm{SAV},n} \quad [4]$$

where ASC_i is the alternative specific constant (ASC) of i, $\mathrm{cost}_{i,n}$ is the travel cost in Japanese Yen (JPY) associated with alternative i and individual n, $\mathrm{time}_{i,n}$ is the travel time in minutes of alternative i and individual n, and $\mathrm{wait}_{\mathrm{SAV},n}$ is the expected waiting time in minutes to get on an SAV. β_{cost}, $\beta_{\mathrm{time,RV}}$, $\beta_{\mathrm{time,PAV}}$, $\beta_{\mathrm{time,SAV}}$, and β_{wait} are the coefficients of the explanatory variables. The estimates for the parameters can be found in the following Table 1. Note that all the estimates are statistically and significantly different from zero.

Table 1. Estimation results.

Parameter	Estimate
$\mathrm{ASC}_{\mathrm{RV}}$	3.750
$\mathrm{ASC}_{\mathrm{PAV}}$	-3.500
β_{cost}	-0.015
$\beta_{\mathrm{time,RV}}$	-0.630
$\beta_{\mathrm{time,PAV}}$	-0.450
$\beta_{\mathrm{time,SAV}}$	-0.540
β_{wait}	-1.125

Answer the following questions.

(1) Explain an estimation method for the above model. Note that if you introduce new formulations or notations here, you must define them explicitly.

(2) What do the signs of the estimates suggest? Explain the related behavioral interpretation of each of (a) ASC_{RV} and ASC_{PAV}, (b) β_{cost}, (c) $\beta_{time,RV}$, $\beta_{time,PAV}$, and $\beta_{time,SAV}$, and (d) β_{wait}.

(3) Assume that the waiting time has the largest elasticity on the choice of SAV. What policy would you propose for improving the SAV system to promote the use of SAV? Discuss the policy and its potential adverse effects.

(4) Estimate the Value of Travel Time Saving (VTTS) in JPY/hour of each of the three alternatives. Then, explain your interpretation regarding the difference in the estimated VTTSs.

(5) Imagine the near future when autonomous vehicles are practically available and people can own and use AVs more easily. Based on the estimated VTTSs, what impacts would you expect on travel behavior and urban land use? Explain your projection in about five lines in English or four lines in Japanese. (You may or may not consider a specific city/region.)

stated preference (SP) survey: 表明選好調査,
alternative: 選択肢,
autonomous vehicle (AV): 自動運転車,
ride-hailing service: 配車サービス,
discrete choice model: 離散選択モデル,
independently and identically distributed (i.i.d.): 独立同一分布に従う
Gumbel distribution: ガンベル分布,
statistically and significantly: 統計的有意に,
estimation method: 推定法,
behavioral interpretation: 行動(論)的解釈,
elasticity: 弾力性,
projection: (未来に対する) 予測
transportation mode choice: 交通手段選択,
regular vehicle: 普通自動車,
shared AV: 共有型自動運転車,
pickup and drop-off points: 乗車・降車場所,
utility function: 効用関数,
alternative specific constant: 選択肢固有定数,
explanatory variable(s): 説明変数,
notation(s): 表記法・記号,
adverse effect(s): 悪影響・副作用,
Value of Travel Time Saving (VTTS): 所要時間短縮価値,
travel behavior: 交通行動,

分野 7 / Field 7: (Spatial information engineering)

(1) Answer the following questions.
   a) Explain the functionality of the Global Navigation Satellite System (GNSS) referring to three satellites in use, in about 3 lines in English or 2 lines in Japanese.
   b) Explain the principles of absolute and relative positioning with GNSS, in about 5 lines in English or 4 lines in Japanese.
   c) List three advantages and three disadvantages of GNSS surveying in about 5 lines in English or 4 lines in Japanese.

(2) Figure 1 shows an example of a synthetic aperture radar (SAR) image. The region with stronger / weaker backscatter intensity appears brighter / darker in the image. Answer the following questions.
   a) Explain why the use of SAR rather than a real aperture radar (RAR), is the only practical option for radar imaging from space, in about 3 lines in English or 2 lines in Japanese.
   b) Name and illustrate with a diagram the scattering processes that occur in each of the following three land uses: high-rise buildings, forests, and water bodies.
   c) Sketch a graph of incidence angle versus backscatter intensity for both forests and water bodies.

Figure 1. Synthetic aperture radar (SAR) image.

functionality: 機能, absolute positioning: 単独測位, relative positioning: 相対測位, synthetic aperture radar (SAR): 合成開口レーダー, real aperture radar (RAR): 実開口レーダー, backscatter intensity: 後方散乱強度, incidence angle: 入射角

分野 8/Field 8:（Urban / Landscape）

Answer the following questions.

(1) It is important to consider the sequential landscape of urban public spaces to realize cities where people can enjoy walking.

a) Explain differences between sequential landscape and scenic landscape, in about three lines.

b) The sequential changes of spatial relationships between pedestrians and their surroundings are one of the essential factors for the quality of walking experiences in urban public spaces. Give and describe an example of what you consider to be enjoyable walking experiences in urban public spaces, in about four lines.

c) Propose a design strategy for urban public spaces where people can enjoy walking as they experience a sequential landscape, in about seven lines.

(2) Japan has a regulatory system that building forms are primarily controlled by restricting building coverage ratios and floor area ratios.

a) Explain the building coverage ratio and the floor area ratio, in one line each.

b) Discuss a method for planning townscapes which are pleasant for pedestrians under this system for controlling building forms, in about seven lines.

sequential landscape: シークエンス景観　　scenic landscape: シーン景観
sequential changes: 次々に起こる変化　　spatial relationships: 空間的な関係性
pedestrian: 歩行者　　surroundings: 周囲　　strategy: 戦略、方策
building coverage ratio: 建ぺい率　　floor area ratio: 容積率　　townscape: 街並み

分野 9/Field 9: (Management)

Figure 1 shows the recent trends in: (a) the daily labor costs for public works officially estimated by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) and; (b) the average daily wage of subcontractors in construction. This figure highlights the relationship between the labor costs borne by the employers and the actual labor wages in public works in Japan. Note that the officially estimated daily labor cost is defined as the wage level that subcontractors' site workers should daily receive, and that these estimated labor costs are in fact reflected in the contract prices. It can be seen that the estimated daily labor cost rose from 15,175 Japanese Yen (JPY) per person in 2013 to 22,227 JPY in 2023, up 46%, on average among the 12 main types of construction work. In contrast, the average daily wage of subcontractors in construction rose from 15,117 JPY per person in 2013 to 18,983 JPY, up only 26%.

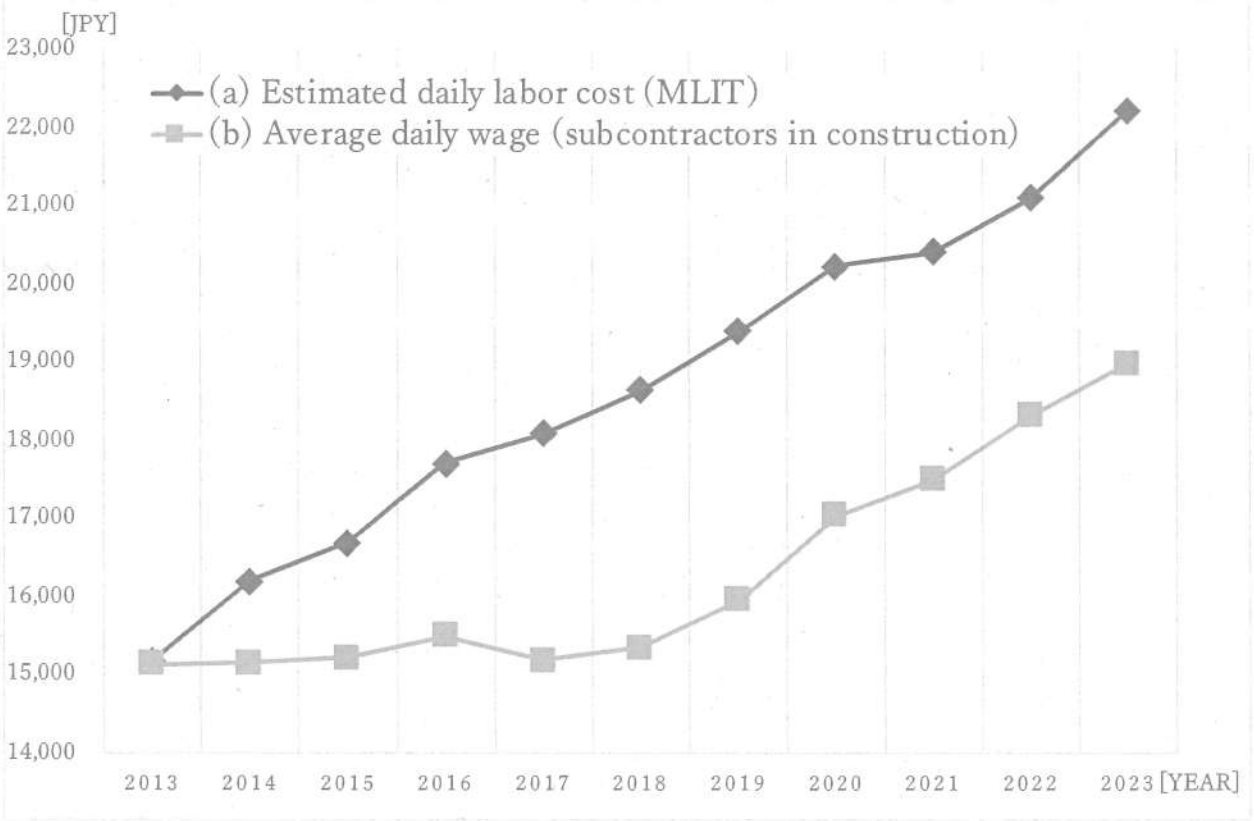


Figure 1

Answer the following questions.

(1) It is argued that the main cause of the difference in the above two percentage rises lies in its industrial structure, often referred to as the multi-layer subcontracting system. Describe firstly why

the entire supply chain of the construction industry tends to form such a multi-layer subcontracting system, and secondly why this industrial structure can explain the difference in those percentage rises.

(2) Recently, the Japanese government are introducing the prevailing wage rates, below which a construction contract is outlawed as unreasonably low price sales. Discuss how this new policy can affect the gap between the two trends discussed above.

(3) Though the introduction of the prevailing wage rates intuitively seems to cause higher construction costs, the past studies, empirical or theoretical, are surprisingly not conclusive on this causality. Discuss what conditions or mechanisms could make the overall construction cost *unaffected* by the introduction of the prevailing wage rates.

Daily labor costs for public works officially estimated by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT): 国土交通省日当たり公共工事設計労務単価, Labor wages: 労務賃金,
Subcontractors: 下請事業者, Borne by …: …によって負担される,
Employers: 発注者, Public works: 公共工事, Site workers: 建設作業従事者,
Contract prices: 契約金額, Types of construction work: 建設業職種, Industrial structure: 産業構造,
Referred to as…: …と呼ばれる, Multi-layer subcontracting system: 重層下請構造,
Prevailing wage rates: 標準労務費, Outlawed: 違法となる, Unreasonably low price sales: 廉売行為,
Intuitively: 直感的に, Empirical: 実証的, Conclusive: 結論が出ている,
Causality: 因果関係, Unaffected: 影響されない

分野 10/Field 10: (International Project)

Read the following text and answer the four questions below.

In the urban metropolises of the Global South, informal transportation options such as minibuses, tuk-tuks, cyclos (trishaws) and motorbikes, enable those with limited financial means to access services and employment, and to move goods for themselves or small-scale businesses.(A) With limited large-scale, planned transportation schemes, these alternatives are often the only means by which millions of people can travel on a daily basis, making a major contribution to urban mobility. Yet increasingly, such means of transportation are being seen as outdated and obsolete, failing to fit modern urban transportation ideals,(B) with policies being implemented to restrict their operations. Such policies increase mobility injustice.(C)

Source: Turner, S. (2020). Journal of Transport Geography, 85, 102728. Partially modified from the original text.

(1) Regarding the underlined part (A), why do many urban metropolises of the Global South have informal transportation options? Explain the reasons in about six lines in English or about four lines in Japanese.
(2) Regarding the underlined part (B), what are the modern urban transportation ideals in contrast to informal transportation? List four factors that constitute such ideals.
(3) Regarding the underlined part (C), what kinds of mobility injustice are typically caused by the policies restricting informal transportation? Explain them from the viewpoints of users and drivers within three lines in English or two lines in Japanese for each.
(4) Recently, new transportation options with advanced technology, such as online-based ridehailing and delivery services, have been increasingly popular in many urban metropolises of the Global South. Such new transportation services may accelerate the mobility injustice by undermining the existing informal transportation. What kinds of policy should be introduced for harmonizing the new transportation options with the existing informal transportation? Describe your proposals on the policy in about eight lines in English or about six lines in Japanese.

metropolis: 大都市, means: 手段, outdated: 時代遅れ, obsolete: 古臭い,
ideal: 理念, 理想, restrict: 制限する, injustice: 不公正, 不公平, constitute: 構成する,
ridehailing: 配車サービス, delivery: 配達, undermine: 阻害する, harmonize: 調和させる

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受験番号 examinee number

「社会基盤学」問題冊子

Question Booklet of "Civil Engineering"

2025年度大学院入試 東京大学大学院工学系研究科社会基盤学専攻 博士後期課程

The 2025 Entrance Examination Doctoral program, Department of Civil Engineering, Graduate School of Engineering, The University of Tokyo

2024年8月26日（月）14:40 – 15:30（日本時間）August 26th, 2024 (Monday) 14:40 – 15:30 (in JST)

分野1 (Field 1)	構造・設計 (Structures / Design)
分野2 (Field 2)	材料 (Concrete engineering)
分野3 (Field 3)	地盤 (Geotechnical engineering)
分野4 (Field 4)	水圏工学A (Hydrospheric engineering A)
分野5 (Field 5)	水圏工学B (Hydrospheric engineering B)
分野6 (Field 6)	交通 (Transportation)
分野7 (Field 7)	空間情報 (Spatial information engineering)
分野8 (Field 8)	都市・景観 (Urban / Landscape)
分野9 (Field 9)	マネジメント (Management)
分野10 (Field 10)	国際プロジェクト (International project)
分野11 (Field 11)	数学 (Mathematics) 別冊**(Separate Booklet)**

注意事項 / Notices

- 本問題冊子表紙の右上に受験番号を記載してください。Write your examinee number at the upper right box of this page.
- 日本語もしくは英語で、解答すること。Answers must be written in Japanese or English.
- 1分野に対して解答すること。どの1分野を解答したかを解答分野申告用紙に記入すること。解答分野申告用紙での申告と異なる分野の解答は採点されません。Answer the questions in the one exam field. Write your answered exam field in the Declaration Form of answered exam fields. If you answer questions in an exam field different from that you selected in the form, your answers will not be scored.
- 分野ごとに、1枚ずつ解答用紙を使用してください。Please use one answer sheet for each field.
- 解答用紙は分野1-10の解答用である「社会基盤学」と書かれた用紙が1枚と、分野11の解答用である「数学」と書かれた用紙1枚の、計2枚配られる。解答分野申告用紙に記入された1分野に対応する1枚の解答用紙が採点対象となり、残る1枚は採点されない。You received one answer sheet named "Civil Engineering", which should be used to answer Field 1-10, and one answer sheet named "Mathematics", which should be used to answer Field 11. Totally you received 2 answer sheets. One answer sheet which corresponds to one field you write in the Declaration Form of an answered exam field will be scored and the remaining sheet will not be scored.
- 分野1-10の解答にあたっては、解答用紙の所定の欄に受験番号と分野番号を記入してください。When you answer Field 1-10, please fill your examinee number and exam field number for the answer sheet.
- 分野11(数学)は別冊になります。6問中1問を選択して解答してください。解答用紙の所定の欄に受験番号と問題番号を記入してください。 You can find problems of Field 11 (Mathematics) in the separate booklet. Please select one problem out of six problems. Please fill your examinee number and write the problem number that you answer in the boxes of the answer sheet.
- 解答に用いなかった解答用紙1枚についても受験番号を記入の上、左上の欄に「N/A」と記入すること。For an answer sheet which you did not use for answering, you must write "N/A" in the upper left box. Your examinee number should also be written.
- 解答用紙の裏面を使用しても構いません。解答用紙を追加することはできません。You can use both sides of the answer sheets. Additional answer sheets are not available.
- 試験終了時には、問題冊子および解答用紙をすべて回収します。You must return the booklets and all the answer sheets after the examination.

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分野 1/Field 1: (Structures / Design)

Consider the vibration response of a construction transport vehicle being loaded with soil of weight $m_S g$ as shown in Figure 1(A). Assume that the vehicle can be modeled as a damped linear single-degree-of-freedom system with a mass m_V, damping coefficient c_V, and spring constant k_V, as shown in Figure 1(B). Answer the following questions under the assumption that the vehicle's damping ratio $\zeta_V = c_V/(2\sqrt{m_V k_V})$ is less than 1, and m_V is significantly larger than m_S.

The definitions of mathematical symbols and variables are as follows:

- t: Time
- g: Gravitational acceleration.
- $x(t)$: Vertical displacement of the vehicle in Figure 1(B) and Figure 2 based on a stationary coordinate system. The displacement in the stationary state before loading the soil is 0.

(1) Write the vibration equation of the vehicle when the external force due to the soil is $f(t)$.

(2) Let's determine the displacement response $x(t)$ of the vehicle for $t \geq 0$ when the external force $f(t)$ is given by the following equation [1]. The displacement response $x(t)$ can be expressed as the sum of a particular solution ($x_p(t)$) of the vibration equation for forced vibration and the general solution ($x_h(t)$) of the vibration equation for free vibration when the external force is zero. Determine both $x_p(t)$ and $x_h(t)$. The undetermined constants of the general solution can be left as they are.

$$f(t) = \begin{cases} 0 & (t < 0) \\ m_S g & (t \geq 0) \end{cases} \qquad [1]$$

(3) Determine the minimum and maximum values of $x(t)$ assuming that the damping ratio of the vehicle is extremely small and can be neglected, and then sketch the graph of $x(t)$ showing the minimum and maximum values. The initial conditions are $x(0) = 0$ and $\dot{x}(0) = 0$.

Next, at time $t = 0$ right after the soil was loaded as described in equation [1], the vehicle started moving at a certain velocity on an uneven road surface, as shown in Figure 2.

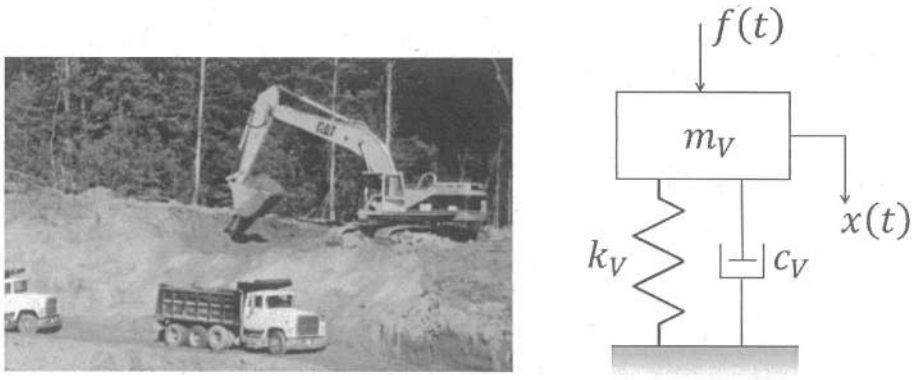
The definitions of mathematical symbols and variables are as follows:

- $y(t)$: Elevation of the uneven road surface in Figure 2 based on a stationary coordinate system.
- Y: Amplitude of the elevation of the uneven road surface in Figure 2.
- ω: Circular frequency of the uneven road surface in time.
- $\omega_n = \sqrt{k_V/m_V}$: Natural circular frequency of the vehicle.

(4) Write the vibration equation for the vehicle shown in Figure 2 assuming that $y(t)$ is given by equation [2], and then determine its particular solution.

$$y(t) = Y\sin(\omega t) \quad (t \geq 0) \qquad [2]$$

(5) At time $t = \pi/\omega_n$, determine the condition that ω/ω_n must satisfy for the displacement response $x(t)$ to be smaller than the maximum value obtained in (3). The initial conditions are $x(0) = 0$ and $\dot{x}(0) = 0$. Assume that the damping ratio of the vehicle is extremely small and can be neglected.



(A)* (B)

Figure 1. A damped linear single-degree-of-freedom system.

* Source of the photo: A. Stentz et al., "A Robotic Excavator for Autonomous Truck Loading," *Autonomous Robots*, Vol.7, No.2, pp.175-186, 1999.

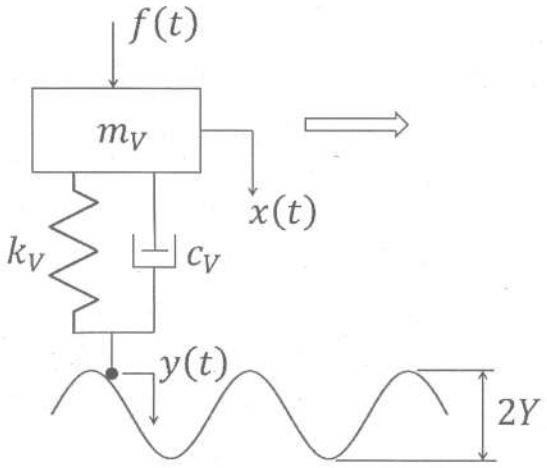


Figure 2. A damped linear single-degree-of-freedom system moving on an uneven road surface.

Construction Transport Vehicle：建設用運搬車両, A Damped Linear Single-degree-of-freedom System：減衰のある線形 1 自由度系, Mass：質量, Damping Coefficient：減衰係数, Spring Constant：ばね定数, Damping

Ratio：減衰比, m_V is significantly larger than m_S: m_Vはm_Sより十分大きい

Gravitational Acceleration：重力加速度, Vertical Displacement：鉛直方向の変位, Stationary State：静止状態, Stationary Coordinate System：静止座標系, Natural Circular Frequency：固有円振動数

Vibration Equation：振動方程式, Displacement Response：変位応答, External Force：外力, Particular Solution：特殊解(特解), Forced Vibration：強制振動, General Solution：一般解, Free Vibration：自由振動, Initial Conditions：初期条件, Undetermined Constants：未定定数

Uneven Road Surface：凹凸のある路面, Elevation：高さ

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分野 2/Field 2: (Concrete engineering)

(1) Answer the following questions.

a) Consider the section of a reinforced concrete (RC) member with materials' properties given in Figure 1. Show the calculation process when answering the questions. Do not use safety factors.

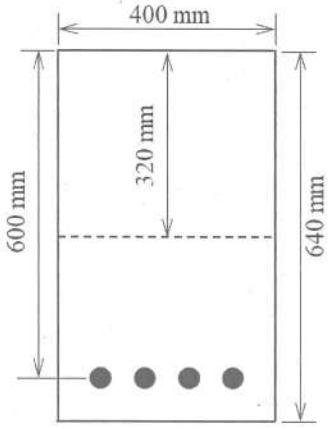
a-I) When the RC member is subjected to only flexural moment, calculate the ultimate flexural capacity (moment) at failure.

a-II) Consider a situation that 1,000,000 N of axial force is applied to center height of the section of the RC member. When the RC member is subjected to flexural moment under the situation, calculate the ultimate flexural capacity (moment) at failure.

b) Pre-stressing forces in pre-stressed concrete beams are often eccentric. Explain the reason in about 3 lines. You may use illustrations, if needed.

c) Explain the important concept in the design of RC members for toughness in ultimate state by using all the following keywords, in about 3 lines. Underline each keyword when it first appears in the answer.

Keywords: *Flexural compression failure, Shear failure, Brittle failure*



Black dot (●) indicates a reinforcing steel bar
Dotted line indicates center height of section

Total cross-sectional area of reinforcements: $A_s = 4{,}000$ mm^2
Yield strength of reinforcement: $f_y = 350$ N/mm^2
Elastic modulus of reinforcement: $E_s = 200{,}000$ N/mm^2
Compressive strength of concrete: $f'_c = 35$ N/mm^2
Ultimate compressive strain of concrete: $\varepsilon'_u = 0.0035$

Figure 1. Reinforced concrete section and material properties.

(2) Answer whether each of the following statements is TRUE or FALSE. If it is FALSE, write the reason in about 2 lines, referring to the scientific mechanisms.

a) It is important to ensure sufficient air content in hardened concrete to reduce frost damage of concrete. The sizes and spacing of the air bubbles are not important for this purpose.

b) Use of blast furnace slag powder as a cement substitution increases chloride binding of concrete, which reduces the steel corrosion resistance of RC against salt attack.

c) Use of fly ash as a cement substitution generally degrades the workability of fresh concrete.

d) Moderate-heat Portland cement is often used in high-strength concrete with low water-cement ratios and high cement content. Moderate-heat Portland cement is therefore less commonly

used in dam concrete with low cement content.

e) Honeycombs appearing in early age concrete are generally due to segregation during casting, which is caused by several factors, such as insufficient compaction and inappropriate mix proportion.

section: 断面, member: 部材, safety factor: 安全係数, flexural moment: 曲げモーメント,
ultimate flexural capacity: 曲げ耐力, axial force: 軸力, pre-stressing force: プレストレス力, beam: 梁(桁),
eccentric: 偏心, design: 設計, toughness: 靭性, flexural compression failure: 曲げ圧縮破壊,
shear failure: せん断破壊, brittle failure: 脆性破壊, reinforcing steel bars (reinforcements): 補強鉄筋,
yield strength: 降伏強度, elastic modulus: 弾性係数, compressive strength: 圧縮強度,
ultimate compressive strain: 圧縮破壊ひずみ,

sufficient: 十分な, air content: 空気量, frost damage: 凍害, spacing: 間隔, air bubble: 空気泡,
blast furnace slag powder: 高炉スラグ微粉末, cement substitution: セメント代替,
chloride binding: 塩化物固定, corrosion: 腐食, salt attack: 塩害, fly ash: フライアッシュ,
degrade: 悪化させる, workability: ワーカビリティ, fresh concrete: フレッシュコンクリート,
moderate-heat Portland cement: 中庸熱ポルトランドセメント, water-cement ratio: 水セメント比,
honeycombs: ジャンカ(豆板), segregation: 材料分離, casting: 打込み, compaction: 締固め,
mix proportion: 配合

分野 3/Field 3:(Geotechnical engineering)

(1) Answer the following questions on liquefaction phenomena of ground.

a) Explain the mechanism of liquefaction in sandy ground during an earthquake, in about 3 lines.

b) List three factors that affect the onset of liquefaction during earthquake, and explain their physical mechanism in about 3 lines in total.

(2) Answer the following questions on active earth pressure on retaining wall.

a) Explain the concept of obtaining the active earth pressure based on (i) Rankine's earth pressure theory and (ii) Coulomb's earth pressure theory, in about 4 lines in total.

b) Explain three conditions for the actual active earth pressure on the retaining wall to be equal to that obtained by Rankine's earth pressure theory.

(3) Hollow cylindrical torsional shear test is often used for evaluating the strength and deformation characteristics of soil. Explain the characteristics of the hollow cylindrical torsional shear test in about 3 lines, including its advantage and disadvantage.

(4) Excessive groundwater pumping can cause significant fall of groundwater level and ground settlement. Consider the ground shown in Figure 1. Here, GL indicates the ground level. The groundwater level is initially GL−5.0 m, then lowered to GL−10.0 m by the groundwater pumping. Estimate the ground settlement due to the effect of groundwater lowering, by answering the following questions.

Here, the settlement of the sand layer can be ignored. Degree of saturation of the sand layer above the groundwater level is S_r=50%, water density is ρ_w=1.0 g/cm^3, compression index of clay layer is C_c=0.9, and gravitational acceleration is g=10 m/s^2. If necessary, the following values can be used; $\log_{10}2=0.30$, $\log_{10}3=0.48$, $\log_{10}5=0.70$, $\log_{10}7=0.85$, $\log_{10}11=1.04$.

(a) Calculate the following three values:

- saturated unit weight of sand
- saturated unit weight of clay
- wet unit weight of sand above the groundwater level

(b) Draw a figure of the vertical distributions of pore water pressure (hydrostatic pressure), u:

- when the groundwater level is GL−5.0 m using a solid line
- when the groundwater level is GL−10.0 m using a broken line

(c) Draw a figure of the vertical distributions of vertical effective stress, σ_v':

- when the groundwater level is GL−5.0 m using a solid line
- when the groundwater level is GL−10.0 m using a broken line

(d) Calculate effective vertical stress at the middle height of the clay layer (GL−14.0 m) when the groundwater level is GL−5.0 m and GL−10.0 m, respectively.

(e) Calculate the change of void ratio in the clay layer and the approximate value of settlement, using the result of (d).

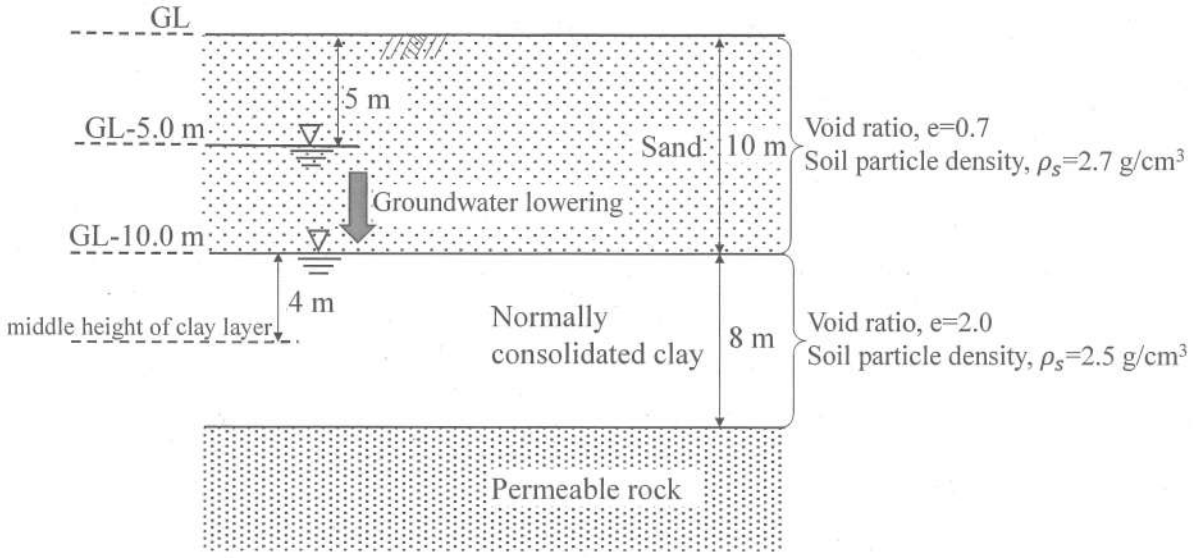


Figure 1. Ground condition and groundwater level.

onset of liquefaction:液状化の発生

active earth pressure:主働土圧, retaining wall:擁壁, Rankine's earth pressure theory:ランキンの土圧理論, Coulomb's earth pressure theory:クーロンの土圧理論, actual:実際の

hollow cylindrical torsional shear test:中空ねじりせん断試験,
strength and deformation characteristics of soil:土の強度および変形特性

excessive groundwater pumping: 過剰な地下水のくみ上げ, groundwater level:地下水位, settlement:沈下, degree of saturation:飽和度, water density:水の密度, compression index of clay layer: 粘土層の圧縮指数, gravitational acceleration:重力加速度, saturated unit weight:飽和単位体積重量,
wet unit weight:湿潤単位体積重量, vertical distribution: 深度分布, pore water pressure:間隙水圧, hydrostatic pressure:静水圧, vertical effective stress:鉛直有効応力, void ratio:間隙比,
approximate value:概略値, solid line:実線, broken line:破線, respectively: それぞれ,
soil particle density:土粒子密度, normally consolidated clay:正規圧密粘土, permeable:透水性のある

分野 4/Field 4: (Hydrospheric engineering A)

A circular-crested dam holds stationary water up to its crest level as illustrated in Figure 1. We define the x-axis as extending horizontally downstream from the upstream toe of the dam, the z-axis upward from the dam crest level and the y-axis perpendicular to both the x and z axes (see Figure 1). The dam cross-section is semicircular with radius R and uniform in the y direction. Answer the following questions. Density of water is ρ and gravitational acceleration is g. Assume atmospheric pressure to be zero.

(1) Find the resultant horizontal force of water pressure on the dam per unit length in the y direction.

(2) Find the bulk density required for the dam to remain stable against sliding. Assume a static friction coefficient of 0.5 between the dam and the ground surface.

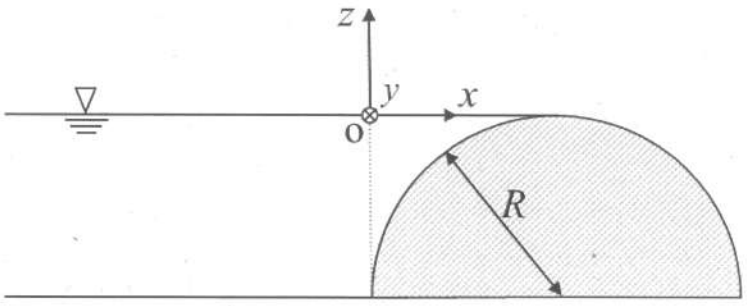


Figure 1. Cross-section of a circular-crested dam holding stationary water.

Upstream water discharge raises the water level and generates a steady state as illustrated in Figure 2. The upstream flow, away from the dam ($x < -R$), can be considered a uniform horizontal flow. The upstream flow velocity is $U = \sqrt{gR}/6$, which is assumed to be uniform throughout the depth. The water surface elevation from the dam crest level, $\eta(x)$, is approximated by the following function:

$$\frac{\eta(x)}{R} = \frac{1}{2} - \frac{1}{24}\left(\frac{x}{R} + 1\right)^2 \quad \text{for} \quad -R \le x \le R. \qquad [1]$$

Answer the following questions. Neglect the flow friction on the bed including the dam surface. You may introduce additional approximations as needed, but they should be stated explicitly.

(3) Find the depth-averaged horizontal velocity above the dam crest ($x = R$) using mass conservation.

(4) Find the pressure at the upstream toe of the dam, $(x, z) = (0, -R)$, using energy conservation.

(5) The flow velocity satisfies the following kinematic condition along the water surface:

$$u\frac{d\eta}{dx} = w \quad \text{for} \quad z = \eta(x), \tag{2}$$

where u and w are horizontal and vertical velocity components, respectively. Find u and w at the water surface above the dam crest, $(x, z) = (R, \eta(R))$.

(6) Find u and w at the dam crest, $(x, z) = (R, 0)$, based on the assumption that the horizontal velocity component varies linearly with the depth above the dam crest.

(7) Draw a sketch of the vertical distribution of pressure above the dam crest ($x = R$), based on the assumption in (6).

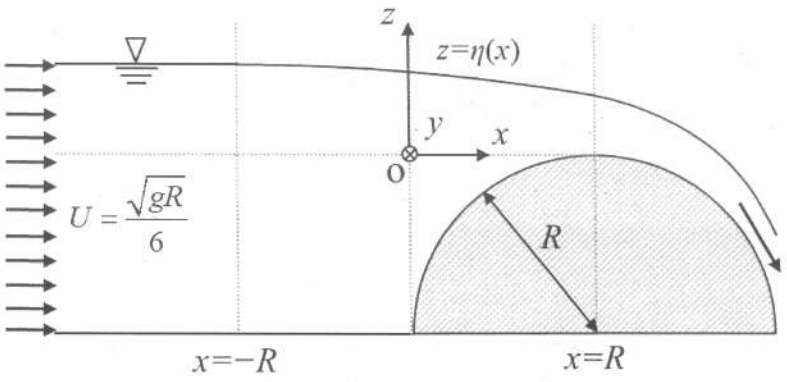


Figure 2. A steady flow over the circular-crested dam.

circular-crested dam: 円形状の頂部を有するダム, stationary water: 静止した水, crest: 頂部, upstream toe: 上流側の下端, perpendicular: 垂直な, semicircular: 半円形の, radius: 半径, density: 密度, gravitational acceleration: 重力加速度, atmospheric pressure: 大気圧, resultant horizontal force: 水平合力, bulk density: かさ密度, sliding: 滑動, static friction coefficient: 静止摩擦係数, discharge: 流量, steady state: 定常状態, uniform horizontal flow: 一様な水平流, flow friction: 流れによる摩擦, bed: 底面, approximation: 近似, depth-averaged: 水深平均の, mass conservation: 質量保存, energy conservation: エネルギー保存, velocity component: 流速成分, kinematic condition: 運動学的条件, linearly: 直線的に

分野 5/Field 5: (Hydrospheric engineering B)

(1) Regarding the following statements about climate change, answer whether each statement is TRUE or FALSE. If it is FALSE, explain the reason.

a) According to the IPCC AR6 (Intergovernmental Panel on Climate Change 6th Assessment Report), it is still difficult to conclude that the rise in global air temperature since the Industrial Revolution is certainly due to greenhouse gas emissions by humans, because there are many other factors that affect Earth's climate.

b) The Paris Agreement requires all member nations to decide targets to reduce greenhouse gas emissions, regardless of their level of responsibility for past emissions.

c) The amount of water vapor that the atmosphere can hold increases along with air temperature rise. As a result, annual mean precipitation is expected to increase in all regions of the world.

d) Compared to local-scale meteorological extremes such as heavy rainfall, river discharge reflects basin-wide-scale water circulation processes. Thus, it is relatively easy to identify the impact of climate change from long-term data on annual maximum river discharge.

(2) Countermeasures against climate change can be classified into "mitigation measures" and "adaptation measures". Answer the following questions regarding these countermeasures.

a) Write the definitions and examples of "mitigation measure" and "adaptation measure" in about 4 lines in total.

b) In the Paris Agreement, "keeping a global temperature rise this century well below 2 °C above pre-industrial levels" was decided as a globally common target for mitigation measures, while such common target was not made for adaptation measures. Explain why setting globally common target is difficult for adaptation measures in about 3 lines.

c) What are the potential benefits for developed countries to support adaptation measures in developing countries? Explain in about 3 lines, citing multiple examples of the benefits.

(3) Due to the intensification of river flooding under climate change, it is becoming difficult to avoid losses and damages by floods only through the conventional flood control measures, such as dams and levees to prevent inundation outside of river areas. Therefore, various flood risk reduction measures that go beyond conventional measures are currently being considered.

Consider several flood risk reduction measures that are effective in reducing losses and damages from large-scale flood hazards. Discuss how these measures can reduce flood risk and what difficulties are expected in implementing them, within 10 lines in total.

Use ***at least five keywords*** from the list below, and underline each when it first appears.

Keywords: Basin-wide approach, Land use, Flood forecasting, Multiple stakeholders, Green infrastructure, Co-benefit, Compensation, Reinforcement

Intergovernmental Panel on Climate Change: 気候変動に関する政府間パネル, 6th Assessment Report: 第 6 次評価報告書, Industrial Revolution: 産業革命, certainly: 間違いなく, greenhouse gas emission: 温室効果ガス排出, Paris Agreement: パリ協定, member nations: 加盟国, regardless of: 関係なく, responsibility for past emissions: 過去の排出に対する責任, water vapor: 水蒸気, atmosphere: 大気, annual mean precipitation: 年平均降水量, meteorological extreme: 極端気象現象, heavy rainfall: 豪雨, river discharge: 河川流量, basin-wide-scale: 流域規模, identify: 特定する, annual maximum: 年最大値

countermeasure: 対策, mitigation measure: 緩和策, adaptation measure: 適応策, pre-industrial: 産業革命前の, citing: 参照しつつ

intensification: 激化, losses and damages: 損失と被害, conventional flood control measure: 従来型の洪水制御対策, levee: 堤防, inundation: 氾濫, river area: 河川区域, flood risk reduction measure: 洪水リスク低減対策, implementing: 実施, underline: 下線を引く
basin-wide approach: 流域全体にわたるアプローチ, land use: 土地利用, flood forecasting: 洪水予測, multiple stakeholders: 複数の利害関係者, green infrastructure: グリーンインフラストラクチャー, co-benefit: 相互利益, compensation: 補償, reinforcement: 強化

分野 6/Field 6: (Transportation)

Consider that you have conducted a stated preference (SP) survey on transportation mode choice with three alternatives: regular vehicle (RV), private (personally owned) autonomous vehicle (PAV), and shared autonomous vehicle (SAV). Here, the SAV system is a driverless ride-hailing service. Passengers of SAVs send a request specifying pickup and drop-off points using a mobile application, and the system assigns vehicles through a matching algorithm (e.g., matching the request with the nearest vehicle).

Now you want to analyze the SP data by estimating the following discrete choice model. The utility function of individual n choosing alternative i is defined as:

$$U_{i,n} = V_{i,n} + \varepsilon_{i,n} \quad [1]$$

where $\varepsilon_{i,n}$ follows an independently and identically distributed (i.i.d.) Gumbel distribution with the location parameter being zero and the scale parameter being one, and $V_{i,n}$ are defined as follows:

$$V_{\mathrm{RV},n} = \mathrm{ASC}_{\mathrm{RV}} + \beta_{\mathrm{cost}}\mathrm{cost}_{\mathrm{RV},n} + \beta_{\mathrm{time,RV}}\mathrm{time}_{\mathrm{RV},n} \quad [2]$$

$$V_{\mathrm{PAV},n} = \mathrm{ASC}_{\mathrm{PAV}} + \beta_{\mathrm{cost}}\mathrm{cost}_{\mathrm{PAV},n} + \beta_{\mathrm{time,PAV}}\mathrm{time}_{\mathrm{PAV},n} \quad [3]$$

$$V_{\mathrm{SAV},n} = \beta_{\mathrm{cost}}\mathrm{cost}_{\mathrm{SAV},n} + \beta_{\mathrm{time,SAV}}\mathrm{time}_{\mathrm{SAV},n} + \beta_{\mathrm{wait}}\mathrm{wait}_{\mathrm{SAV},n} \quad [4]$$

where ASC_i is the alternative specific constant (ASC) of i, $\mathrm{cost}_{i,n}$ is the travel cost in Japanese Yen (JPY) associated with alternative i and individual n, $\mathrm{time}_{i,n}$ is the travel time in minutes of alternative i and individual n, and $\mathrm{wait}_{\mathrm{SAV},n}$ is the expected waiting time in minutes to get on an SAV. β_{cost}, $\beta_{\mathrm{time,RV}}$, $\beta_{\mathrm{time,PAV}}$, $\beta_{\mathrm{time,SAV}}$, and β_{wait} are the coefficients of the explanatory variables. The estimates for the parameters can be found in the following Table 1. Note that all the estimates are statistically and significantly different from zero.

Table 1. Estimation results.

Parameter	Estimate
$\mathrm{ASC}_{\mathrm{RV}}$	3.750
$\mathrm{ASC}_{\mathrm{PAV}}$	-3.500
β_{cost}	-0.015
$\beta_{\mathrm{time,RV}}$	-0.630
$\beta_{\mathrm{time,PAV}}$	-0.450
$\beta_{\mathrm{time,SAV}}$	-0.540
β_{wait}	-1.125

Answer the following questions.

(1) Explain an estimation method for the above model. Note that if you introduce new formulations or notations here, you must define them explicitly.

(2) What do the signs of the estimates suggest? Explain the related behavioral interpretation of each of (a) ASC_{RV} and ASC_{PAV}, (b) β_{cost}, (c) $\beta_{time,RV}$, $\beta_{time,PAV}$, and $\beta_{time,SAV}$, and (d) β_{wait}.

(3) Assume that the waiting time has the largest elasticity on the choice of SAV. What policy would you propose for improving the SAV system to promote the use of SAV? Discuss the policy and its potential adverse effects.

(4) Estimate the Value of Travel Time Saving (VTTS) in JPY/hour of each of the three alternatives. Then, explain your interpretation regarding the difference in the estimated VTTSs.

(5) Imagine the near future when autonomous vehicles are practically available and people can own and use AVs more easily. Based on the estimated VTTSs, what impacts would you expect on travel behavior and urban land use? Explain your projection in about five lines in English or four lines in Japanese. (You may or may not consider a specific city/region.)

stated preference (SP) survey: 表明選好調査,
alternative: 選択肢,
autonomous vehicle (AV): 自動運転車,
ride-hailing service: 配車サービス,
discrete choice model: 離散選択モデル,
independently and identically distributed (i.i.d.): 独立同一分布に従う
Gumbel distribution: ガンベル分布,
statistically and significantly: 統計的有意に,
estimation method: 推定法,
behavioral interpretation: 行動(論)的解釈,
elasticity: 弾力性,
projection: (未来に対する) 予測
transportation mode choice: 交通手段選択,
regular vehicle: 普通自動車,
shared AV: 共有型自動運転車,
pickup and drop-off points: 乗車・降車場所,
utility function: 効用関数,
alternative specific constant: 選択肢固有定数,
explanatory variable(s): 説明変数,
notation(s): 表記法・記号,
adverse effect(s): 悪影響・副作用,
Value of Travel Time Saving (VTTS): 所要時間短縮価値,
travel behavior: 交通行動,

分野 7 / Field 7: (Spatial information engineering)

(1) Answer the following questions.
   a) Explain the functionality of the Global Navigation Satellite System (GNSS) referring to three satellites in use, in about 3 lines in English or 2 lines in Japanese.
   b) Explain the principles of absolute and relative positioning with GNSS, in about 5 lines in English or 4 lines in Japanese.
   c) List three advantages and three disadvantages of GNSS surveying in about 5 lines in English or 4 lines in Japanese.

(2) Figure 1 shows an example of a synthetic aperture radar (SAR) image. The region with stronger / weaker backscatter intensity appears brighter / darker in the image. Answer the following questions.
   a) Explain why the use of SAR rather than a real aperture radar (RAR), is the only practical option for radar imaging from space, in about 3 lines in English or 2 lines in Japanese.
   b) Name and illustrate with a diagram the scattering processes that occur in each of the following three land uses: high-rise buildings, forests, and water bodies.
   c) Sketch a graph of incidence angle versus backscatter intensity for both forests and water bodies.

Figure 1. Synthetic aperture radar (SAR) image.

functionality: 機能, absolute positioning: 単独測位, relative positioning: 相対測位, synthetic aperture radar (SAR): 合成開口レーダー, real aperture radar (RAR): 実開口レーダー, backscatter intensity: 後方散乱強度, incidence angle: 入射角

分野 8/Field 8: (Urban / Landscape)

Answer the following questions.

(1) It is important to consider the sequential landscape of urban public spaces to realize cities where people can enjoy walking.

a) Explain differences between sequential landscape and scenic landscape, in about three lines.

b) The sequential changes of spatial relationships between pedestrians and their surroundings are one of the essential factors for the quality of walking experiences in urban public spaces. Give and describe an example of what you consider to be enjoyable walking experiences in urban public spaces, in about four lines.

c) Propose a design strategy for urban public spaces where people can enjoy walking as they experience a sequential landscape, in about seven lines.

(2) Japan has a regulatory system that building forms are primarily controlled by restricting building coverage ratios and floor area ratios.

a) Explain the building coverage ratio and the floor area ratio, in one line each.

b) Discuss a method for planning townscapes which are pleasant for pedestrians under this system for controlling building forms, in about seven lines.

sequential landscape: シークエンス景観　　scenic landscape: シーン景観
sequential changes: 次々に起こる変化　　spatial relationships: 空間的な関係性
pedestrian: 歩行者　　surroundings: 周囲　　strategy: 戦略、方策
building coverage ratio: 建ぺい率　　floor area ratio: 容積率　　townscape: 街並み

分野 9/Field 9: (Management)

Figure 1 shows the recent trends in: (a) the daily labor costs for public works officially estimated by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) and; (b) the average daily wage of subcontractors in construction. This figure highlights the relationship between the labor costs borne by the employers and the actual labor wages in public works in Japan. Note that the officially estimated daily labor cost is defined as the wage level that subcontractors' site workers should daily receive, and that these estimated labor costs are in fact reflected in the contract prices. It can be seen that the estimated daily labor cost rose from 15,175 Japanese Yen (JPY) per person in 2013 to 22,227 JPY in 2023, up 46%, on average among the 12 main types of construction work. In contrast, the average daily wage of subcontractors in construction rose from 15,117 JPY per person in 2013 to 18,983 JPY, up only 26%.

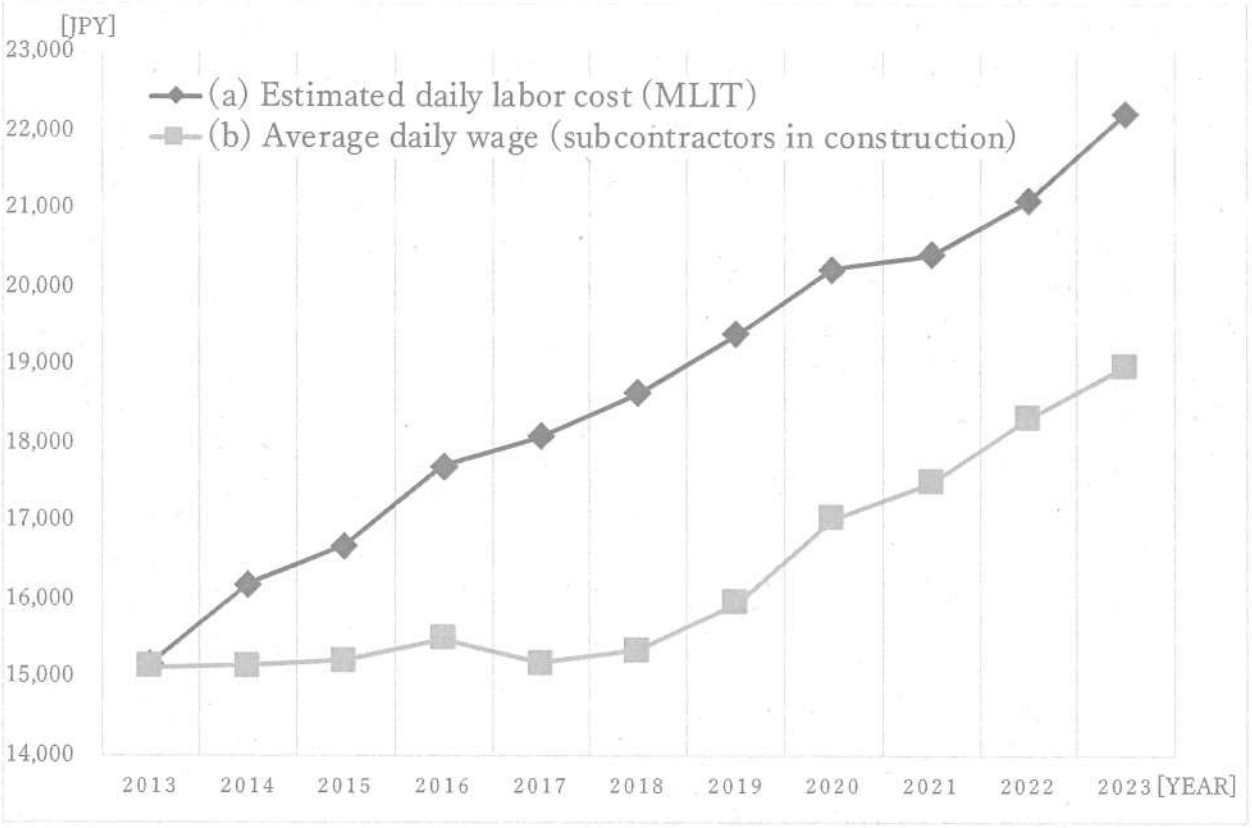


Figure 1

Answer the following questions.

(1) It is argued that the main cause of the difference in the above two percentage rises lies in its industrial structure, often referred to as the multi-layer subcontracting system. Describe firstly why

the entire supply chain of the construction industry tends to form such a multi-layer subcontracting system, and secondly why this industrial structure can explain the difference in those percentage rises.

(2) Recently, the Japanese government are introducing the prevailing wage rates, below which a construction contract is outlawed as unreasonably low price sales. Discuss how this new policy can affect the gap between the two trends discussed above.

(3) Though the introduction of the prevailing wage rates intuitively seems to cause higher construction costs, the past studies, empirical or theoretical, are surprisingly not conclusive on this causality. Discuss what conditions or mechanisms could make the overall construction cost *unaffected* by the introduction of the prevailing wage rates.

Daily labor costs for public works officially estimated by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT): 国土交通省日当たり公共工事設計労務単価, Labor wages: 労務賃金,
Subcontractors: 下請事業者, Borne by …: …によって負担される,
Employers: 発注者, Public works: 公共工事, Site workers: 建設作業従事者,
Contract prices: 契約金額, Types of construction work: 建設業職種, Industrial structure: 産業構造,
Referred to as…: …と呼ばれる, Multi-layer subcontracting system: 重層下請構造,
Prevailing wage rates: 標準労務費, Outlawed: 違法となる, Unreasonably low price sales: 廉売行為,
Intuitively: 直感的に, Empirical: 実証的, Conclusive: 結論が出ている,
Causality: 因果関係, Unaffected: 影響されない

分野 10/Field 10: (International Project)

Read the following text and answer the four questions below.

In the urban metropolises of the Global South, informal transportation options such as minibuses, tuk-tuks, cyclos (trishaws) and motorbikes, enable those with limited financial means to access services and employment, and to move goods for themselves or small-scale businesses.(A) With limited large-scale, planned transportation schemes, these alternatives are often the only means by which millions of people can travel on a daily basis, making a major contribution to urban mobility. Yet increasingly, such means of transportation are being seen as outdated and obsolete, failing to fit modern urban transportation ideals,(B) with policies being implemented to restrict their operations. Such policies increase mobility injustice.(C)

Source: Turner, S. (2020). Journal of Transport Geography, 85, 102728. Partially modified from the original text.

(1) Regarding the underlined part (A), why do many urban metropolises of the Global South have informal transportation options? Explain the reasons in about six lines in English or about four lines in Japanese.
(2) Regarding the underlined part (B), what are the modern urban transportation ideals in contrast to informal transportation? List four factors that constitute such ideals.
(3) Regarding the underlined part (C), what kinds of mobility injustice are typically caused by the policies restricting informal transportation? Explain them from the viewpoints of users and drivers within three lines in English or two lines in Japanese for each.
(4) Recently, new transportation options with advanced technology, such as online-based ridehailing and delivery services, have been increasingly popular in many urban metropolises of the Global South. Such new transportation services may accelerate the mobility injustice by undermining the existing informal transportation. What kinds of policy should be introduced for harmonizing the new transportation options with the existing informal transportation? Describe your proposals on the policy in about eight lines in English or about six lines in Japanese.

metropolis: 大都市, means: 手段, outdated: 時代遅れ, obsolete: 古臭い,
ideal: 理念, 理想, restrict: 制限する, injustice: 不公正, 不公平, constitute: 構成する,
ridehailing: 配車サービス, delivery: 配達, undermine: 阻害する, harmonize: 調和させる

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