共通問題 / Common Question

In recent years, severe natural disasters have frequently occurred, such as the Great East Japan Earthquake (2011), Heavy rain in West Japan (2018), and Typhoon Hagibis (2019). Effective management of infrastructures is essential to protect our lives from these disasters and to establish sustainable society.

Management of infrastructures including survey, plan, design, construction, operation, maintenance and renovation processes is currently facing variety of problems (e.g. consideration of larger external force under ongoing climate change; conservation of local environment and culture for future generations; ensuring resilient infrastructure system under difficult situations such as economic recession and population decrease). These problems are sometimes in trade-off relationships, e.g. focusing on one side makes it difficult to improve the other side. Civil engineers are often required to overcome multiple problems that are in trade-off relationships in the management of infrastructure. Regarding the trade-off problems, what kind of challenges should we tackle with in "Civil Engineering" now for making our society better? Answer all the following questions within 2 pages in total. (You may use figures, tables and equations if needed.)

(1) Raise one example in which civil engineers are required to overcome multiple problems that are in trade-off relationships in the management of infrastructure.
Note: You may choose a "hard" structure and/or a "soft" system as an example of the management of infrastructure.

(2) Regarding the example you have raised in question (1), what approaches have been proposed to solve the trade-off problems so far? Introduce one previous or ongoing approach with appropriate references to literatures and/or specific cases. In addition, explain the limitations of the approach you introduced.

(3) What knowledge and/or technology gap must be filled in regarding the example you have raised in question (1)? Explain what academic research or policy making that you think will be necessary in the future to overcome the limitation of the previous approach you introduced in question (2).

Great East Japan Earthquake: 東日本大震災,
Typhoon Hagibis: 2019 年台風 19 号,
Resilient: 復元力のある,
Heavy rain in West Japan: 西日本豪雨
External force: 外力
Economic recession: 経済停滞

注：2021年度はオンライン試験を実施した。試験期間は１週間で,、教科書やウェブページなどを参照可とした。
Note: FY2021 exam was conducted online. The exam period was 1 week. Reference to textbook and webpage was allowed.

分野 1 / Field 1: (Structures / Design)

大問 1 / Question 1

Answer all the following questions considering the cantilever beam with a uniform rectangular cross section shown in Figure 1. Assume that the beam is made of a homogeneous linear elastic material with Young's modules E, shear modulus G and Poisson's ratio ν. u_x is the axial displacement of the beam at a cross section perpendicular to beam axis, and $u_y(x)$ is the vertical displacement of the beam due to the external load P (see Figure 1).

(1) Write the main assumptions of the Euler-Bernoulli beam theory

(2) In Euler-Bernoulli beam theory, the bending induced axial deformation is approximated as $u_x(x,y) = -y\frac{\mathrm{d}u_y}{\mathrm{d}x}$. Derive the corresponding fourth order governing differential equation for the vertical displacement u_y.

(3) Prove that Euler-Bernoulli assumptions produce zero shear strain (i.e. $\epsilon_{xy} = 0$). According to continuum mechanics, shear strain $\epsilon_{xy} = \frac{1}{2}\left(\frac{\partial u_x}{\partial y} + \frac{\partial u_y}{\partial x}\right)$.

(4) Consider a cross-section perpendicular to the beam axis at an arbitrary location x (see Figure 1 (b)).

a) What are the conditions that must be satisfied by each of axial stress σ_{xx} and transverse shear stress σ_{xy} to maintain the equilibrium in axial and vertical directions respectively?

b) Write the boundary conditions that must be satisfied by σ_{xy} at $y = \pm\frac{h}{2}$.

c) Which of the above conditions are satisfied by the Euler-Bernoulli beam theory?

(5) As you proved in the question (3), the assumptions of Euler-Bernoulli beam theory produce zero shear strain, and hence zero shear stress. However, as you showed in question (4)a), static equilibrium requires the presence of non-zero shear stress. Assume that, with the aim of eliminating this shear inconsistency of the Euler-Bernoulli beam theory, you are planning to approximate the bending induced axial deformation as

$$u_x(x,y) = -f(y)\frac{\mathrm{d}u_y}{\mathrm{d}x} + g(y). \qquad [1]$$

Both the $f(y)$ and $g(y)$ are odd function (i.e. $f(-y) = -f(y)$, and $g(-y) = -g(y)$) with continuous first derivatives. Some examples of odd functions are x, x^3 and $\sin x$.

Obtain the expressions for the following quantities in terms $f(y)$, $g(y)$ and u_y, when u_x is approximated according to Equation [1].

a) axial strain ϵ_{xx} and stress σ_{xx}

b) transverse shear strain ϵ_{xy} and stress σ_{xy}

注：2021年度はオンライン試験を実施した。試験期間は１週間で､、教科書やウェブページなどを参照可とした。
Note: FY2021 exam was conducted online. The exam period was 1 week. Reference to textbook and webpage was allowed.

(6) Explain why you cannot use even functions for $f(y)$ in Equation [1] for approximating bending induced axial deformation. A function $f(y)$ is even when $f(-y) = f(y)$. Some examples of even functions are x^2 and $\cos x$.

(7) Derive the fourth order governing differential equation for the vertical displacement u_y corresponding to the approximation given in Equation [1]. Clearly state any assumptions required.

(8) Assume that you are planning to consider the following four candidate pairs for $f(y)$ and $g(y)$, with the aim of identifying better performing approximations without inconsistencies.

a) $f(y) = y$ and $g(y) = 0$

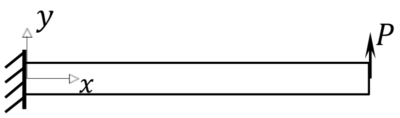
b) $f(y) = y$ and $g(y) = \frac{P}{Ght}y$

c) $f(y) = y$ and $g(y) = \frac{P}{2Gt}\sin\left(\frac{\pi y}{h}\right)$

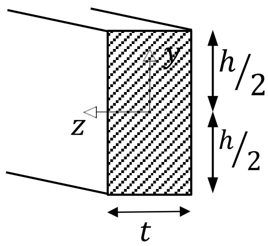
d) $f(y) = y$ and $g(y) = \frac{P}{Ght}\frac{y}{2}\left(3 - 4\frac{y^2}{h^2}\right)$

Discuss the applicability of the each of the above pairs to approximate the axial displacement due to bending and the improvements made by each, considering the accuracy of u_y and the presence of inconsistencies. Clearly explain your reasons in mathematical and mechanical point of views.

(9) Explain the further steps you would take to establish the correctness and validity of the suitable approximations you found among the four pairs given in the question (8).



(a) A cantilever beam



(b) Beam cross-section at arbitrary x

Figure 1 A cantilever beam subjected to a point load P, and its cross section.

Cantilever beam: 片持ち梁, Linear elastic material: 線形弾性体, Young's modules: ヤング率
Shear modulus: 剛性率, Poisson's ratio: ポアソン比, Perpendicular: 垂直な
Euler-Bernoulli beam theory：ベルヌーイ・オイラー梁理論, Shear strain: せん断ひずみ
Arbitrary: 任意の, Equilibrium：平衡 , Shear stress: せん断応力
Odd function: 奇関数, Even function：偶関数, First derivative: 1 階微分
Transverse: 横断

分野 1 / Field 1:

大問 2 / Question 2

Consider the model house shown in Figure 1. Note that $0.9m$ and $0.1m$ are the masses of the 1st and 2nd floors, $k/2$ and $k/4$ are the horizontal stiffnesses of each of the two columns supporting the 1st and 2nd floors, x_1 and x_2 are the displacements of the 1st and 2nd floors. Answer all the following questions. You may use a calculator.

(1) Approximate the model house as a linear two-degree-of-freedom system shown in Figure 1. Derive the equation of motion of the system in matrix form and obtain the eigenvalues and eigenvectors for the first and second modes.

(2) Since the mass of the second floor is small, the system can be simplified as a linear single-degree-of-freedom system. Consider the structural damping ratio to be $\xi = 2.5\%$ shown in Figure 2. Let's call this "original design". Derive the steady-state responses (displacement and acceleration) of the system subject to the horizontal ground acceleration given in Equation [1].

$$a_g = 0.3\sin(1.4\omega t) + \sin(\omega t) + \sin(0.5\omega t). \qquad [1]$$

Here, t is the time and ω is the natural angular frequency of the system.

(3) Consider the stiffness to be $k_1 = 2k$ shown in Figure 3. Let's call this "design concept 1". Derive the steady-state responses (displacement and acceleration) of the system subject to the ground acceleration shown in Equation [1].

(4) Consider the damping ratio to be $\xi_1 = 5\%$ shown in Figure 4. Let's call this "design concept 2". Derive the steady-state responses (displacement and acceleration) of the system subject to the ground acceleration shown in Equation [1].

(5) Assume that the system is supported by two bearings shown in Figure 5. Let's call this "design concept 3". Consider the stiffness of the bearings to be $k_2 = 0.25k$ and the damping ratio to be $\xi = 2.5\%$. Derive the steady-state responses (displacement and acceleration) of the system subject to the ground acceleration shown in Equation [1].

(6) Suppose that the mass m and the natural period $T(= 2\pi/\omega)$ of the model house are 1000 kg and 1 second (s), respectively. The unit of a_g in Equation [1] is m/s^2. Comparing with the "original design" in the question (2), explain quantitatively how each of the "design concepts 1, 2, 3" described in the questions (3), (4) and (5) influence the maximum displacement (m) and maximum acceleration (m/s^2) of the model house. Also, write the technical terms of the engineering techniques corresponding to each of those "design concepts 1, 2, and 3".

(7) Assume that the natural period of the approximate model house can vary between 0.7 second and 2 second and the damping ratio ξ can vary between 2.5% and 5%. Derive the optimal values of natural period and damping ratio based on your own idea to mitigate the maximum displacement and acceleration and explain quantitatively why these values are optimal.

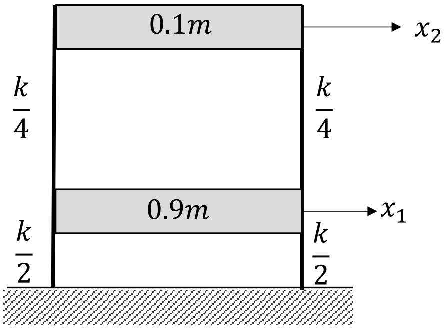
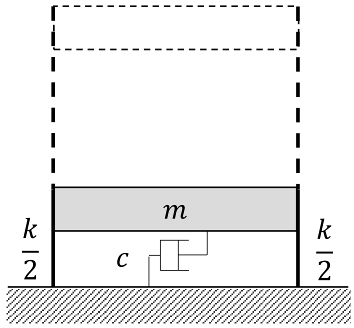
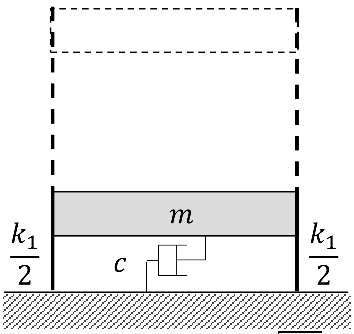


Figure 1 A model house



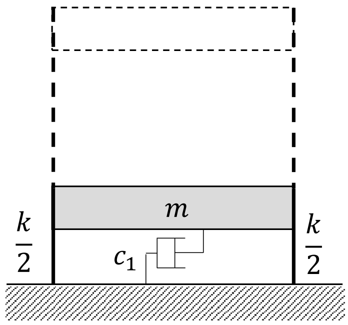
$c = 2\xi\sqrt{mk}$

Figure 2 Original design



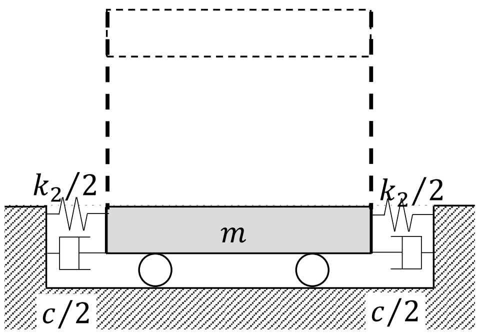
$k_1 = 2k$ $c = 2\xi\sqrt{mk}$

Figure 3 Design concept 1



$c_1 = 2\xi_1\sqrt{mk}$

Figure 4 Design concept 2



$k_2 = 0.25k$ $c = 2\xi\sqrt{mk}$

Figure 5 Design concept 3

Stiffness: 剛性,
Eigenvalue: 固有値,

Steady-state response:定常応答
Eigenvector: 固有ベクトル

分野 2/Field 2: (Concrete engineering / Geotechnical engineering)

大問 1 /Question 1

Read the following sentences and answer the questions (1)-(4). Answer within around 0.5 page for each question and within 2 pages in total.

More than 100 years have passed since we started using concrete materials for infrastructures. In the meantime, we have understood the various characteristics of concrete materials and structures and (a) we have been reviewing the technical standards every time an earthquake or other natural disaster occurs. We have conducted various studies and improvements and have applied them to the construction of many infrastructures.

In the field of civil engineering, recently, there has been a great deal of interest in maintenance and management of the structures which were constructed during the high economic growth period. In addition, the efficiency of maintenance and management is being improved in anticipation of a shortage of workers in the near future of a super-aging society. In this context, we should conduct research to improve the efficiency of reinforcement of existing structures and to develop materials that can be used for a longer period.

In the field of architectural engineering, the criteria for determining life span are different from civil engineering. In many cases, although there is no problem in terms of function, (b) the building has been reduced, streamlined, converted, or renewed from the viewpoint of usability, so that it can be used for a long time, rather than simply demolishing the old one and building a new one. Various efforts have been made for the long-term preservation of (c) historical structures.

On the other hand, it is commonly known that the life cycle management should be considered at the stage of new construction, so that it is necessary to construct (d) durable concrete structures, and various efforts have been made in design, materials and construction.

The common idea behind these efforts is to build better concrete structures in Japan, where the terrain is complex and the natural environment is severe, and to use them efficiently with limited financial resources to serve society for as long as possible.

(Excerpted from *Concrete Journal, Vol.57(5)* by Japan Concrete Institute, translated into English)

(1) Regarding the underlined part (a), explain the meaning of each of the following listed words in the seismic design of concrete structures. And explain the important concepts in the seismic design of concrete structures by using all the following listed words.
[Recoverability, Redundancy, Robustness, Bending failure, Shear failure]

(2) Regarding the underlined part (b), the reuse of structures or structural members shall be considered as well in civil engineering concrete structures in the future. Give an example of a civil engineering concrete structure that can be suitable for the reuse of structural members and explain why it is suitable, and how it can be reused. Then, describe a possible technical difficulty and an idea for solving it. (The term "reuse" here means not the reuse of concrete in the form of materials such as crushed recycled aggregate, but the reuse of each structure or each member.)

(3) Related to the underlined part (c), Table 1 shows the concrete mix conditions of a post-tensioned pre-stressed concrete (PC) railway bridge, which is one of the historical civil engineering concrete structures in Japan, constructed in the 1950s. A survey conducted in the early 2000s shows that the quality of the cover concrete remains extremely high, with little or no carbonation.
Point out the differences of the concrete mix conditions between this bridge and the current common PC bridges and discuss the differences in construction and curing methods required to ensure the high quality of the cover concrete according to the differences in the mix conditions. When answering the question, first explain what is "high quality of cover concrete" and give your answer.

Table 1

<table>
<tr><td colspan="2">Water-to-cement ratio</td><td>Slump (cm)</td><td>Compression strength (MPa)</td><td colspan="2">Cement type</td></tr>
<tr><td colspan="2">0.36</td><td>3.0</td><td>45.9</td><td colspan="2">Early Strength Portland Cement</td></tr>
<tr><td colspan="6">Unit weight (kg/m³)</td></tr>
<tr><td>Water</td><td>Cement</td><td colspan="2">Sand</td><td>Gravel</td><td>Chemical Admixture</td></tr>
<tr><td>162</td><td>450</td><td colspan="2">549</td><td>1263</td><td>None</td></tr>
</table>

(4) Related to the underlined part (d), in general, the apparent diffusion coefficients are calculated and used for the verification of steel corrosion due to chloride ion penetration into concrete under the assumption that chloride ion penetration is based on Fick's second law. However, as shown in Figure 1, actual calculated apparent diffusion coefficients tend to vary by more than an order of magnitude, even for the same cement type and water-to-cement ratio. Discuss possible reasons for this variation in the apparent diffusion coefficient.

注：2021年度はオンライン試験を実施した。試験期間は１週間で,、教科書やウェブページなどを参照可とした。
Note: FY2021 exam was conducted online. The exam period was 1 week. Reference to textbook and webpage was allowed.

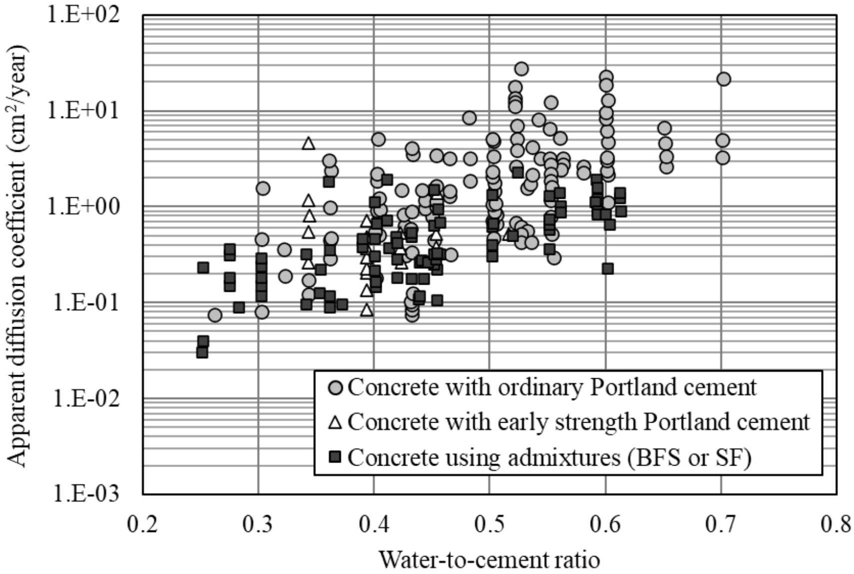


Figure 1

Technical standard: 技術基準,
Durable: 耐久性のある
Seismic design: 耐震設計,
Recoverability: 復旧性
Redundancy: 冗長性,
Robustness: 頑健性
Bending failure: 曲げ破壊,
Shear failure: せん断破壊
Structural member: 構造部材,
Recycled aggregate: 再生骨材
Post-tensioned pre-stressed concrete: ポストテンション式プレストレストコンクリート
Cover concrete: かぶりコンクリート,
Carbonation: 炭酸化
Concrete mix condition: コンクリート配合条件,
Curing: 養生
Apparent diffusion coefficient: 見掛けの拡散係数,
Verification: 照査
Chloride ion penetration: 塩化物イオン浸透,
Fick's second law: Fick の第二法則

分野 2 / Field 2:

大問 2 / Question 2

Answer all the following questions, within 1 page for each question. You can include equations and schematic figures, if necessary.

(1) Describe the differences in physical properties between sand and clay. Also, explain the differences in permeability and consolidation characteristics between sand and clay. Discuss the reasons why such differences appear in permeability and consolidation behavior considering the difference of void ratios between sand and clay.

(2) When an embankment is constructed rapidly on normally consolidated clay ground, it may lead to the failure of the embankment and ground. Explain the reason for this. Describe the measures taken in practice to prevent the failure of the embankment rapidly constructed on the normally consolidated clay.

(3) The results of triaxial compression tests (stress-strain relationships and volumetric strains) of spherical glass beads and sands are presented in Figure 1, as well as their physical properties. Triaxial compression tests were conducted under the effective confining pressure, σ_c', of 100 kPa in the drained condition. Discuss what are the governing factors for the mechanical behavior of granular materials, based on the results presented in Figure 1.

Physical properties：物理特性,
Consolidation：圧密,
Normally consolidated clay：正規圧密粘土,
Triaxial compression test：三軸圧縮試験,
Granular materials：粒状材料
Permeability：透水性
Embankment：盛土
Spherical glass beads：球形のガラスビーズ
Mechanical behavior：力学特性

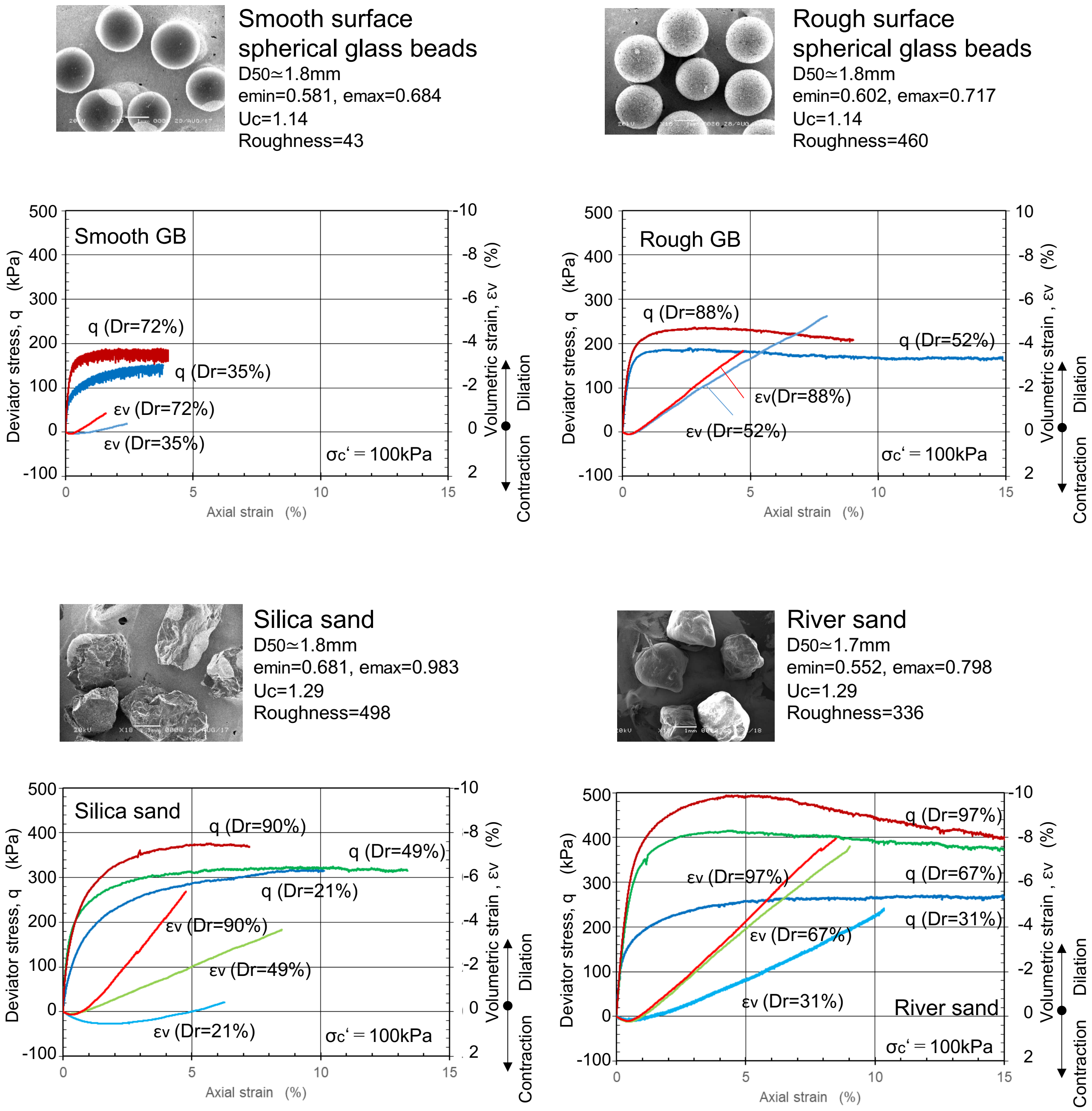


Figure 1

Positive volumetric strains mean contraction: 体積ひずみは圧縮を正とする
D_{50}：Mean particle size 平均粒径, Uc： Coefficient of Uniformity 均等係数
e_{min}：Minimum void ratio 最小間隙比, e_{max}：Maximum void ratio 最大間隙比
Dr：Relative density 相対密度, Deviator stress：偏差応力
Roughness：Roughness of grain surface (The larger, the rougher.)
粒子表面の粗さ（数値が大きいほど粗いことを示す）

分野 3 / Field 3: (Hydrospheric engineering)

大問 1 / Question 1

Euler's equations of motion in three-dimension can be shown as follows under the assumption of constant and uniform density.

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+w\frac{\partial u}{\partial z}=F_x-\frac{1}{\rho}\frac{\partial p}{\partial x} \quad [1]$$

$$\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+w\frac{\partial v}{\partial z}=F_y-\frac{1}{\rho}\frac{\partial p}{\partial y} \quad [2]$$

$$\frac{\partial w}{\partial t}+u\frac{\partial w}{\partial x}+v\frac{\partial w}{\partial y}+w\frac{\partial w}{\partial z}=F_z-\frac{1}{\rho}\frac{\partial p}{\partial z}, \quad [3]$$

where t is time, u, v, w are the flow velocities in x direction, y direction and z direction, ρ is the density, p is the pressure and F_x, F_y, F_z are the components of force along x, y, z axes. For open channel flow, we can obtain the following equation.

$$\frac{1}{gA}\frac{\partial Q}{\partial t}-\frac{2Q}{gA^2}\frac{\partial A}{\partial t}-\frac{Q^2}{gA^3}\frac{\partial A}{\partial x}+\frac{\partial H}{\partial x}=0, \quad [4]$$

where Q is the discharge, g is the gravity acceleration, A is the cross-sectional area of flow normal to the flow direction, H is the water level. Answer all the following questions.

(1) Derive Equation [4] from Euler's equations of motion and explain the assumptions required.

(2) By adding the resistance of channel, following Equation [5] can be derived.

$$\frac{1}{gA}\frac{\partial Q}{\partial t}-\frac{2\beta Q}{gA^2}\frac{\partial A}{\partial t}-\frac{\beta Q^2}{gA^3}\frac{\partial A}{\partial x}+\frac{\partial H}{\partial x}+\frac{1}{\rho gA}\int \tau_b ds=0, \quad [5]$$

where β is the momentum coefficient and is assumed to be 1.0 and constant, τ_b is the bottom shear stress in x direction and s is the wetted perimeter. Under the steady flow condition, Equation [5] can be rewritten as Equation [6] by using Manning's equation in the SI units.

$$\frac{\partial}{\partial x}\left(\frac{Q^2}{2gA^2}+H\right)+\frac{n^2Q^2}{A^2R^{4/3}}=0, \quad [6]$$

where n is Manning's coefficient and R is the hydraulic radius.
Derive Equation [6] from Equation [5].

(3) If the water level H is measured at several cross-sections in a river channel, the area of cross-section A and the hydraulic radius R can be calculated in each cross-section. By using these parameters as well as the interval of each cross-section, Manning's coefficient n of the target river reach can be derived from Equation [7]:

$$n = \frac{1}{Q}\sqrt{\frac{\left(\frac{Q^2}{2gA^2}+H\right)_1 - \left(\frac{Q^2}{2gA^2}+H\right)_m}{\frac{L_{12}}{Z_1Z_2}+\frac{L_{23}}{Z_2Z_3}+\ldots+\frac{L_{(m-1)m}}{Z_{(m-1)}Z_m}}}, \quad [7]$$

where m is the number of cross-sections, $Z_i = A_i R_i^{2/3}$, A_i and R_i are A and R of cross-section i, and L_{ij} is the interval between cross-sections i and j.

In two rivers (River A and River B), several parameters were measured at three cross-sections, respectively. The results are shown in Table 1 and Table 2. L is the interval between two cross-sections, dH are the difference of the water level between two cross-sections, and I is the riverbed slope of the river. In both rivers, water is flowing from cross-section 1 to cross-section 3.

Table 1 River A (Q =22m^3/s, I=1/3500)

cross-section	A(m^2)	R(m)	L(m)	dH(m)
1	26.0	1.5	80	0.028
2	25.5	1.5	60	0.021
3	25.0	1.5		

Table 2 River B (Q =68m^3/s, I=1/285)

cross-section	A(m^2)	R(m)	L(m)	dH(m)
1	38.0	1.4	54	0.18
2	32.0	1.3	45	0.15
3	29.0	1.3		

Based on the results shown in the tables, answer all the following questions.

a) Estimate Manning's coefficient n in River A and River B.

b) Which river flow has more uniform flow? Explain the reason why you think so within 2 lines.

c) Even if a straight river channel with constant width and constant slope is designed, flow can become non-uniform after this river improvement work. Explain the possible reasons within 2 lines.

(4) River improvement works have been carried out to reduce flood damage on our lives and properties. Usually, the water surface profile under design flood discharge is predicted by using equations introduced in the previous questions. Then, a river channel has to be improved so that the water level corresponding to the design flood discharge will be below the design high water level. However, river improvement works which only aim to decrease the water level of the target river section during flood might have negative impacts on flood risk and river environment. In order to increase the level of safety while minimizing these negative impacts, what kind of river improvement works should be planed? Explain your idea as concrete as possible within 1 page.

Euler's equations of motion: オイラーの運動方程式
Momentum coefficient: 運動量補正係数
Bottom shear stress: 底面せん断応力
Wetted perimeter: 潤辺
Steady flow: 定常流
Hydraulic radius: 径深
Uniform flow: 等流
Design flood discharge: 計画高水流量
Design high water level: 計画高水位

分野 3 / Field 3

大問 2 / Question 2

The powerful typhoon, Hagibis, struck East Japan in October 2019, giving significant impacts on the Pacific coasts. Figure 1(a) shows the landfall trajectory of the typhoon with its central pressures based on the typhoon track data of Japan Meteorological Agency (JMA) on a sea bathymetric map. The typhoon made its first landfall at the tip of Izu Peninsula and then propagated on the west side of Tokyo Bay in the northeastern direction. Figures 1(b) and 1(c) show hourly observed sea levels and predicted astronomical tide levels during the passage of the typhoon at Tokyo and Odawara tide stations of JMA, respectively (refer to Figure 1(a) for their locations). Answer all the following questions, within three pages in total.

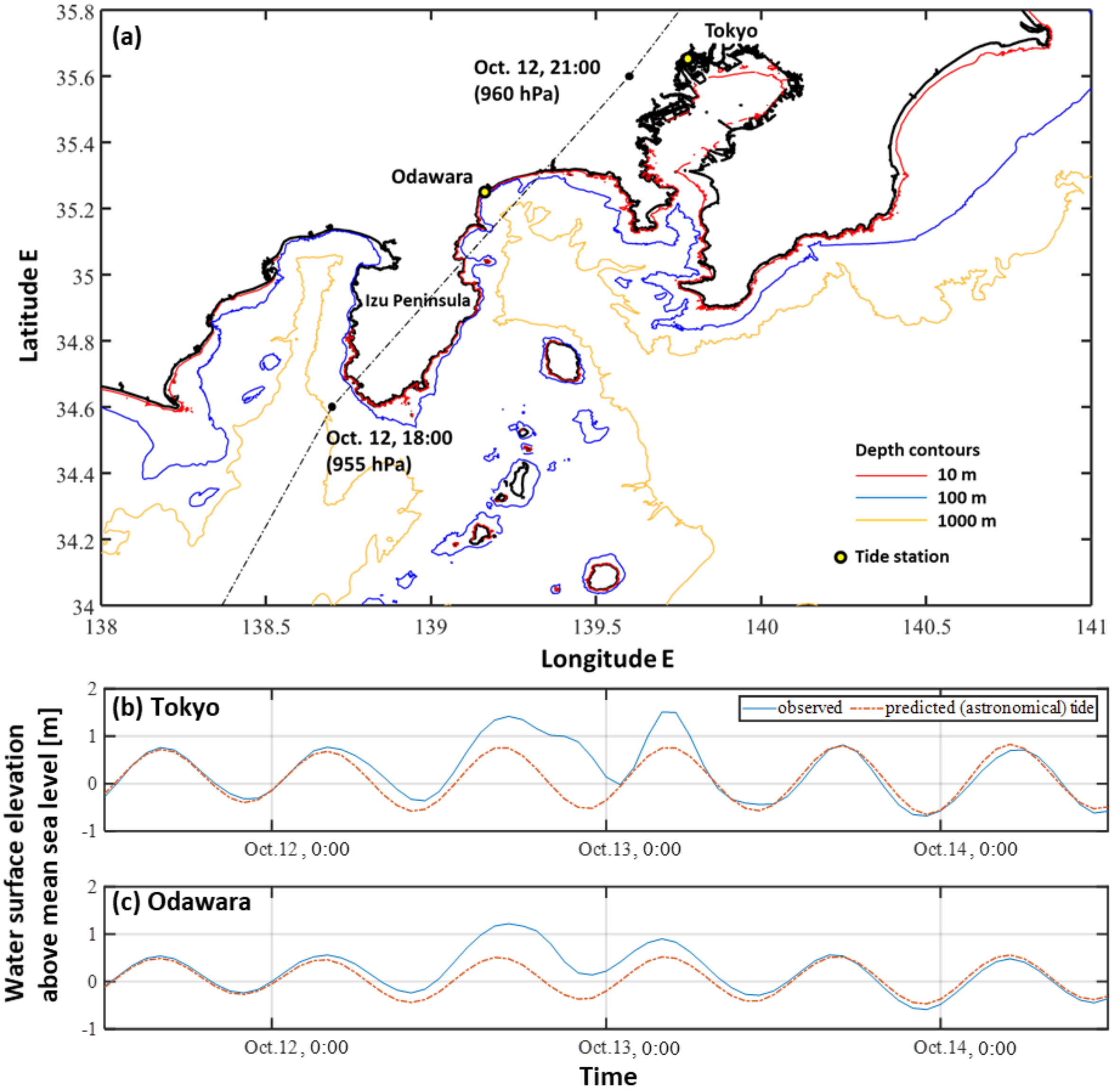


Figure 1

(1) List out and briefly explain possible forcing factors of a typhoon that cause the sea level rise above astronomical tide levels.

(2) Discuss the physical mechanisms underlying the observed sea level rises at the Tokyo and Odawara stations considering contrasting bathymetry and clarifying the contributions of the factors in question (1).

(3) Design high-water level against storm surges in the coastal area of Tokyo is based on a scenario that the strongest typhoon experienced in West Japan (Typhoon Vera in 1959) hits the area with the worst trajectory during a high tide level. Describe your opinion on using the above worst-case scenario based on Typhoon Vera for setting the design high-water level in the coastal area of Tokyo, one of the highly populated low-lying areas in the world.

Sea bathymetric map: 海底地形図
Landfall trajectory: 上陸時の軌道
Astronomical tide: 天文潮
Storm surge: 高潮
Typhoon Vera: 伊勢湾台風

分野 4 / Field 4 (Transportation / Spatial information engineering)

大問 1 / Question 1

You may select and refer to two papers on the travel behavior model and/or the traffic assignment. Give your opinion on theoretical characteristics discussed in the papers, and future research direction that can contribute to transportation planning to solve problems such as congestion and/or evacuation during disasters within 1 page.

Note:

#1 Papers written in English or Japanese.

#2 Examples of journals: Journal of JSCE, Journal of Infrastructure Planning and Management, Transportation Research Part A-Part F, Transportation, Transportation Science, etc.

#3 The quality of the Journals taken up are not criteria for grading

Travel behavior model: 交通行動モデル

Traffic assignment: 交通量配分

Evacuation: 避難

Journal of JSCE：土木学会論文集

Journal of Infrastructure Planning and Management：土木計画学論文集

分野 4 / Field 4

大問 2 / Question 2

(1) Figure 1 shows Landsat 7 band 6 image over Tokyo. Lighter tone indicates higher brightness temperature. Answer all the following questions.

a) You can see evidence of a thermal gradient as you progress from the central Tokyo out into the countryside. Explain why this phenomenon exists in five lines.

b) Explain why brightness temperature is effectively remotely sensed in the 8 – 14 micrometer range in five lines.

c) Landsat 8 has two thermal bands in the 8 – 14 micrometer range although its predecessors have a single band over the region. Explain why two bands can realize much more accurate measurement compared to a single band for land surface temperature retrieval, in five lines.

d) Choose one topic from environmental monitoring studies and discuss your idea on the complementary use of different types of thermal remote sensing satellites in 20 lines.

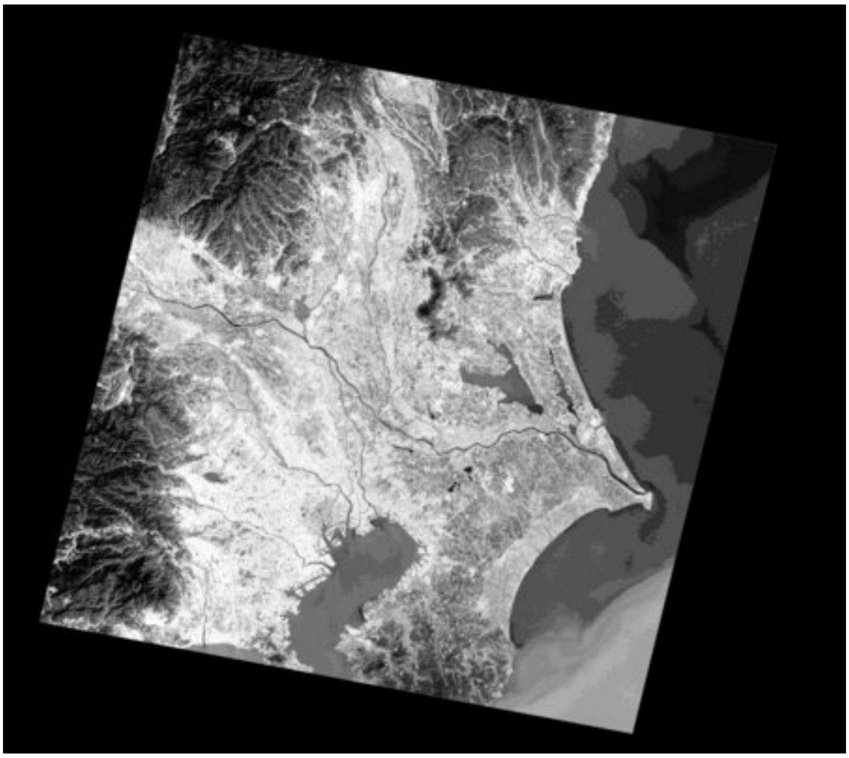


Figure 1

(2) Figure 2 shows a synthetic aperture radar logic for azimuth resolution improvement. Pulses with wavelength λ are transmitted to Target x and received by the antenna with the real aperture antenna length D from $t = -T$ to $t = T$. v is the flight speed of a platform, θ_0 is the angular resolution, L is the synthesized antenna length, and R is the nadir distance from a platform to Target x. Answer all the following questions.

a) Derive the expression for the synthesized antenna azimuth resolution Δr.
b) The synthesized antenna azimuth resolution Δr obtained in question a) is paradoxical to the common sense of antenna engineering. How can we understand this phenomenon? Explain in five lines.
c) In reality, a real aperture antenna length D has constraints. Explain the reason in five lines.
d) Choose one topic from disaster management studies and discuss your own idea on the complementary use of synthetic aperture radar and optical remote sensing in 20 lines.

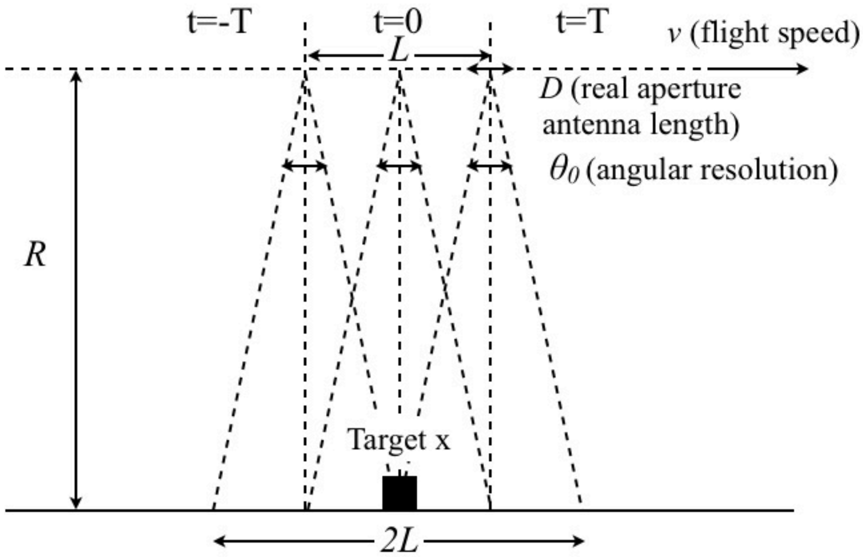


Figure 2

Brightness temperature: 輝度温度
Real aperture antenna length: 実開口アンテナ径
Synthetic aperture radar: 合成開口レーダー
Azimuth resolution: 方位方向の解像度

分野 5 / Field 5 (Urban / Landscape)

大問 1 / Question 1

You may select and refer to two papers on urban planning related to the location planning and population decline. Give your opinion on the location planning in a case we expect frequent natural disasters caused by global warming, and the future research directions within 1 page.

Note:

#1 Papers written in English or Japanese.

#2 Examples of journals: Journal of CPIJ, Journal of Infrastructure Planning and Management, Environment and Planning A-D, Urban Studies, Landscape and Urban Planning, etc.

#3 The quality of the Journals taken up are not criteria for grading

Location planning: 立地計画
Population decline: 人口減少
Global warming: 地球温暖化
Journal of CPIJ: 日本都市計画学会論文集
Journal of Infrastructure Planning and Management: 土木計画学論文集

分野 5 / Field 5:

大問 2 / Question 2

The following text written by Randolph T. Hester, an American landscape architect, gives his opinion that we have to make cities more adaptable by "maintaining flexibility" of urban structures and their spatial elements. And he gives a specific example, a water transportation system in Kyoto, to explain "flexibility" for infrastructural design.

By referring to this text, write a brief essay titled "The importance of designing urban infrastructures more flexible", within 1 page.

Adaptability is the capacity of an ecosystem to adjust for changing conditions with a minimum of unhealthy stress or expenditure of essential resources. In natural systems, the persistence needed to remain healthy and evolve derives from adaptability by "maintaining flexibility above all else." Adaptable cities may be achieved through human choices --- by varying the uses of the environment, changing the form of natural systems, and altering the design of human-made systems. The focus here is city form and the elements of persistence.

In city design, flexibility is achieved by two primary means --- an overall structure that accommodates change while maintaining its fundamental form and a detailed spatial configuration that is malleable enough to fit many functions over time.

Adaptable cities are designed so that many environments serve more than one purpose, connect things not originally thought to be connected, are suitable for new uses, are flexible but not entirely open-ended, and are suggested rather than dictatorial. Instead, cities presently are typically made up of highly specialized, single-purpose components (like highways, sewer plants, and research laboratories) with little flexibility and less adaptability. The trend toward ossified environments will have to be reversed to achieve resilience.

Some landscapes inherently are more adaptable than others. City landscapes that are large, open, and flat generally accommodate more uses than small, enclosed, and steeply sloped spaces. A large open space surrounded by an intricate permeable edge provides greater flexibility than one with a hard edge. When a large open space is subdivided, two spaces of different sizes afford more flexibility than two equally sized. An open space that is paired with its complementary and opposite space (for example, a large, flat space with smaller steeply sloped areas) is more adaptable than either alone. A nodal landscape is more flexible than a linear one.

General, multipurpose landscapes are more flexible than specialized, single-purpose ones. Michael Hough concludes that single-purpose landscape solutions to problems tend to create additional problems. Urban designer Robert Harris, one of the leading architects in revitalizing downtown Los Angeles, suggests that city makers follow this dictum: "We will abide no single-purpose plans." This applies to major public works like water and sewer infrastructure, open-space networks, and neighborhood parks.

Multipurpose action in the design of a major network --- the drinking-water transportation system --- makes Kyoto the finest city landscape I know. Instead of burying the infrastructure in pipes, Kyoto's water courses have historically been left open --- moving water efficiently and providing identifiable boundaries between neighborhoods, places to play in nature, visual and sound delight, and a sense of connectedness throughout the city. The Philosopher's Walk, the most famous part of the system, transports water, provides a place for daily walks, and welcomes spring with cherry blossoms. But lesser known parts are equally multipurpose. I remember sketching in the far north of the city when a teenager stopped to watch me. After a few minutes of quiet, he said that the little canal I was painting had the purest water in all of Kyoto. He told me it was taken from his neighborhood in a two-meter channel to Shimogamo Shrine, four miles away, to be used in purification rituals. Along the route, it provides daily joy to neighbors. I was surprised that a teenager would be interested in the water system. Certainly, he would have been less aware if the channel had been culverted.

Do you know where your drinking water comes from? Do you know what direction it flows in your neighborhood or where the main channel of water is? Neither do I. It makes you wonder why engineers insist on putting water in pipes, diminishing the joy of water running free, disconnecting us from topography, and encouraging ignorance of place. Rigid, single-purpose infrastructure is one opportunity lost.

(Randolph T. Hester, *Design for Ecological Democracy*, 2010; partly revised)

Persistence：粘り強さ
Accommodate：（新たな環境などに）適応する、順応する
Configuration：要素の配置、レイアウト
Malleable：影響を受けやすい、柔軟な
Intricate：入り組んだ、複雑な
Permeable：浸透性のある
Complementary：相補的な
Michael Hough：アメリカのランドスケープ・アーキテクト（1929〜2013）
The Philosopher’s Walk：哲学の道（琵琶湖疏水の一部。京都の観光名所）
Shimogamo Shrine：下鴨神社
Purification rituals：清めの儀式

分野 6 / Field 6: (International project / Management)

大問 1 / Question 1

Imagine that you are a manager of an urban transportation service provider of a specific transportation mode. Your organization is trying to assess the impact of the COVID-19 outbreak on the organization's operational management. Choose one transportation mode, and answer all the following questions:

(1) Summarize the critical impacts that COVID-19 will have on the operational management of your organization.

(2) Categorize the critical impacts into (a) impact(s) that should be addressed immediately, and (b) impact(s) that need(s) to be addressed over the long-term (within 10 years).

(3) Recommend immediate actions to address the short-term impacts in the underlined part (2)-(a). Then, describe what kind of process you would design, and the data you would require to monitor the effectiveness of those immediate action(s).

(4) Suggest an innovative technology, policy, or system, that can fundamentally address, minimize, or prevent the critical impact(s) you have identified in the underlined part (2)-(b). Then, describe how your suggested solution will address, minimize, or prevent those impacts.

You may refer to academic research to justify your recommendations or analysis. All answers should fit within a maximum of 2.5 pages, including references.

分野 6 / Field 6:

大問 2 / Question 2

Suppose you would have the budget equivalent to the annual national budget of the Government of Japan and be allowed to invest all the budget for road infrastructure through a loan program of international development aid during the current fiscal year. Let us examine the most effective allocation of the budget to countries/regions for achieving the Sustainable Development Goals. Answer all the following questions.

(1) What are the expected impacts of road infrastructure on the Sustainable Development Goals? Explain them in approximately one page.

(2) What is (are) the most suitable indicator(s) representing the effectiveness in this context? Explain it (them) in approximately 10 lines.

(3) What is the appropriate method to find the most effective allocation? Propose it in approximately 30 lines.

(4) To which country/region do you think the largest portion of the budget will be allocated when hypothetically applying the above method? Describe the reasons in approximately 20 lines.