Entrance Examination for the 2014,

Department of Civil Engineering,

Graduate School of Engineering, the University of Tokyo

Problems of "Civil engineering"

August 26th 2013 (Monday) 13:00 - 16:00 (180 minutes)

(Fields 1, 5 and 6 are not provided in English.)

Please write your answer to problems in two fields which you have selected on questionnaire sheet. If you answer problems in different fields, your answer shall not be marked.

Please use different answer sheets for different problems (Problem 1, Problem 2). For each of answer sheet you have, please fill your examinee's number, field number, and problem number (e.g. Field 1, Problem 1).
You can use the reverse side of answer sheets. When you require additional answer sheets for fields 1 to 6, please raise your hands. If you use multiple answer sheets for one problem, please put sheet number. You can ask additional answer sheets for calculation.
You have to submit problems, questionnaire sheet, and all answer sheets (including blank sheets or ones for calculation) after the examination.
For Field 7 (Mathematics), please select 2 problems out of 6 problems. Please note that special answer sheets are provided for field 7 and that you cannot use additional answer sheets for field 7.

Field 2 (Concrete Engineering and Geotechnical Engineering)

Problem 1

Answer the following questions.

(1) In general, the ultimate flexural capacity of reinforced concrete members is not proportional to the compressive strength of concrete. Explain this mechanism in approximately 7 lines.

(2) In general, larger amount of shear reinforcement is arranged for large-scale concrete structural members in comparison with the small-sized ones. Explain its mechanical reasons in approximately 7 lines.

(3) It is of great importance in design and planning of structures to avoid catastrophic collapse, and for quick recovery even if a gigantic earthquake beyond the designed magnitude might come. Propose three methods for meeting this challenge in approximately 15 lines.

(4) Explain, in approximately 15 lines, the mix design method of fresh concrete to realize both higher fluidity and segregation resistance by using the following terms. – water to cement (powder) ratio, mineral admixture, water content, super plasticizer, viscosity –.

(5) Propose the methods to improve the corrosion resistance of reinforced concrete located close to coastal lines in view of material design, structural design and construction systems in approximately 20 lines.

Problem 2

A sandy filling of 6 m height, having wet unit weight, γ_t= 20 kN/m^3, is proposed on a soft clay deposit as shown in Fig. 1, where ground water level is equal to the ground surface. In order to investigate the consolidation settlement due to the filling and strength characteristics of the soft clay deposit, oedometer test (one-dimensional consolidation test) and triaxial compression tests were carried out on an undisturbed sample taken from 10 m below the ground level. Answer the following questions.

If necessary, the following values can be used; $\log_{10}2$= 0.3, $\log_{10}3$= 0.48, $\log_{10}4$= 0.6, $\log_{10}8$= 0.9, $\log_{10}16$= 1.2 and $\log_{10}32$= 1.5.

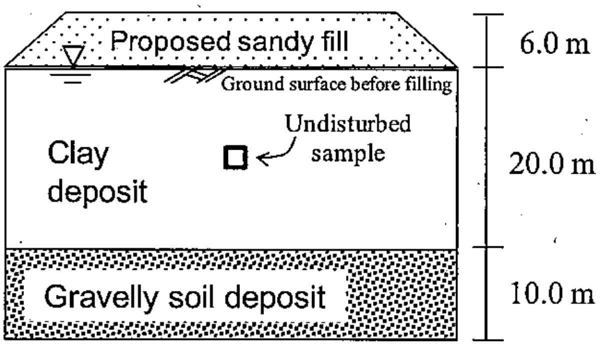

Figure 1 Soil condition before filling

(1) Table 1 shows the result of the oedometer test. The initial height, h_0, and volume, V_0, of the tested cylindrical specimen were 2.0 cm and 56.5 cm^3, respectively. The dry weight, m_s, measured after the test and the soil particle density, ρ_s, of the specimen were 40.0 g and 2.5 g/cm^3, respectively. At the end of the third stage of the test, a vertical strain, ε_v, of 2 % was measured. Consider the density of water, ρ_w= 1.0 g/cm^3 and the unit weight of water, γ_w= 10.0 kN/m^3.

a) Calculate void ratio, e, at the third load stage, and draw a schematic illustration of consolidation curve (e-log$p$ curve).

b) Calculate effective overburden stress at the depth of sampling before the filling and discuss whether the clay deposit is at normally consolidated state or at over consolidated state.

Table 1 Oedometer test result

Load stage	Consolidation pressure, p (kN/m^2)	Void ratio, e
1	10	2.530
2	20	2.497
3	40	[redacted]
4	80	2.190
5	160	1.921
6	320	1.650

(2) Using the experimental data in (1), answer the following questions on the consolidation settlement of clay deposit due to the filling. You can assume that the overburden stress at the center depth of clay deposit before the filling is 40 kN/m^2. Ignore the secondary compression of clay deposit.

a) Calculate the value of compression index, C_c, of the clay deposit.
b) Calculate the value of settlement of clay deposit due to the filling.

(3) Two undisturbed specimens were isotropically consolidated up to 100 kN/m^2, and subjected to drained and undrained triaxial compression tests under constant confining pressure. The effective stress paths obtained from the tests are schematically shown in Fig. 2. Consider the cohesion in terms of effective stress, c'= 0 kN/m^2.

a) Calculate the value of friction angle, ϕ', in terms of effective stress of the clay deposit.
b) Estimate the value of excess pore water pressure, Δu, at the failure state of the specimen under undrained condition.
c) In general, triaxial test under undrained condition is adopted under this situation. Explain why the undrained triaxial test is preferred.

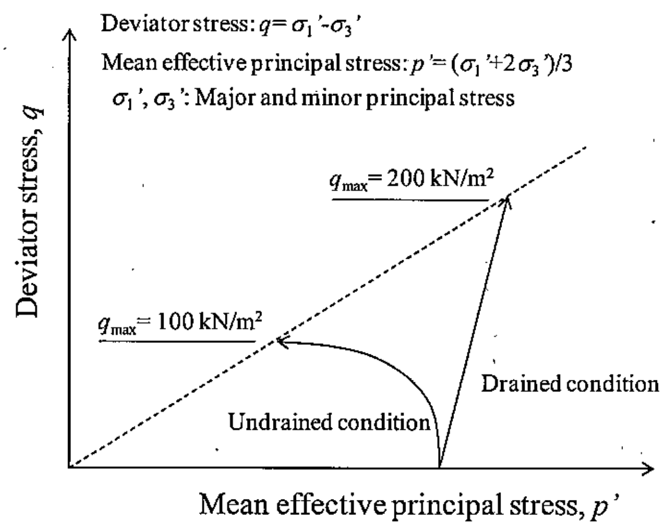

Figure 2 Results of triaxial compression tests (effective stress paths)

(4) Preloading method with vertical drain system improves stability of foundation and ground, and provides faster consolidation of clay deposit. Explain the construction procedure and the improvement mechanism with this method.

Field 3 (Hydrosphere Engineering)

Problem 1

Characteristics of the river flow depend on various conditions such as bed slope, water depth, river width and bed roughness. This problem simplifies the river flow as a straight wide open channel flow and investigates how the flow characteristics change due to the different conditions. As shown in Figure 1, this problem defines: (x, z) as the axis in horizontal and vertical (positive in upward) directions; (u, w) as flow velocity components in x and z directions; t as time; p as water pressure; g as gravity acceleration; ρ as water density; η as water surface level and z_b as channel bed level. Assume that the water density is constant in space and time, z_b should be a function of x, and η should be functions of t and x. Answer the following questions.

(1) Assume that the momentum equations of the flow are expressed by the following equations.

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+w\frac{\partial u}{\partial z}=-\frac{1}{\rho}\frac{\partial p}{\partial x}+\frac{1}{\rho}\frac{\partial \tau_{zx}}{\partial z} \qquad [1]$$

$$\frac{\partial w}{\partial t}+u\frac{\partial w}{\partial x}+w\frac{\partial w}{\partial z}=-\frac{1}{\rho}\frac{\partial p}{\partial z}-g \qquad [2]$$

Here, τ_{zx} is the horizontal shear stress acting in x-direction. <u>Explain the physical meanings of the left-hand-side of equations [1] and [2], respectively, in around 1 to 3 lines.</u>

(2) The water density is assumed to be constant in space and time. Write the equation of mass conservation law (continuity equation).

(3) Combine the mass conservation equation and equations [1] and [2]. Show that these equations [1] and [2] are respectively represented by equations [3] and [4].

$$\frac{\partial u}{\partial t}+\frac{\partial u^2}{\partial x}+\frac{\partial (uw)}{\partial z}=-\frac{1}{\rho}\frac{\partial p}{\partial x}+\frac{1}{\rho}\frac{\partial \tau_{zx}}{\partial z} \qquad [3]$$

$$\frac{\partial w}{\partial t}+\frac{\partial (uw)}{\partial x}+\frac{\partial w^2}{\partial z}=-\frac{1}{\rho}\frac{\partial p}{\partial z}-g \qquad [4]$$

(4) Kinematic boundary conditions either at the water surface or at the channel bed should be defined such that the water particle at the boundary should always move along the boundary. Show that the kinematic boundary conditions at the water surface level and at the channel bed

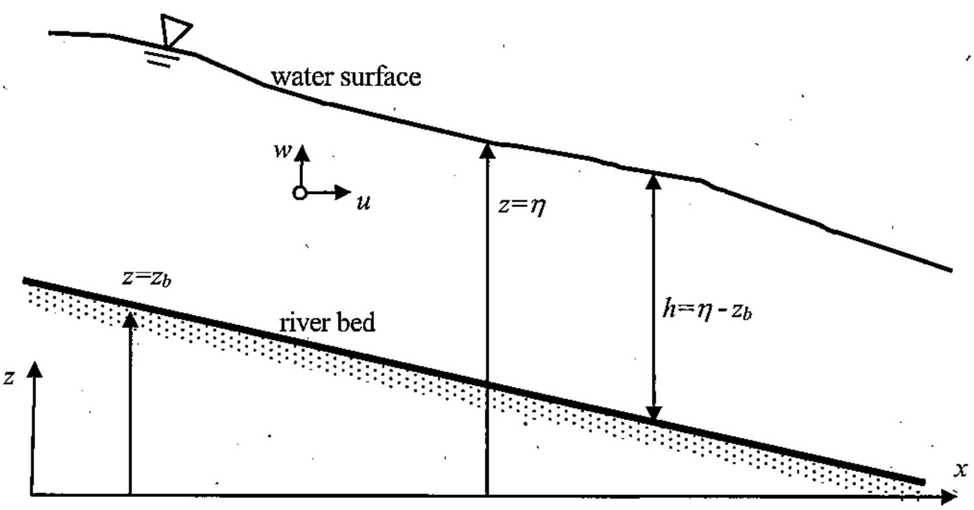

Figure1 Open channel and corresponding coordinate system applied in this problem

are respectively expressed by the following equations [5] and [6].

$$\frac{\partial \eta}{\partial t}+u\frac{\partial \eta}{\partial x}-w=0 \qquad (z=\eta) \qquad [5]$$

$$u\frac{\partial z_b}{\partial x}-w=0 \qquad (z=z_b) \qquad [6]$$

(5) Assume that the time derivative of the flow velocity is negligibly small and the flow velocity is nearly uniform in both flow and vertical directions. Starting from the equation [4], <u>show that the water pressure, p, can be approximated by the following hydrostatic pressure.</u>

$$p=p_0+\rho g(\eta-z) \qquad [7]$$

Here, p_0 is the air pressure and is assumed to be constant in space and time.

(6) Assume that the horizontal velocity, u, is nearly uniform in depth and can be represented by the depth-averaged velocity, U. Integrate the horizontal momentum equation [3] with respect to z from z_b to η, introduce the equation [7] and boundary conditions [5] and [6], and <u>derive the following horizontal momentum equation of the depth-averaged velocity, U.</u>

$$\frac{\partial}{\partial t}(Uh)+\frac{\partial}{\partial x}\left(U^2h\right)=-gh\frac{\partial \eta}{\partial x}+\frac{\tau_{sx}-\tau_{bx}}{\rho} \qquad [8]$$

If necessary, use the following Leibnitz rule.

$$\int_a^b \frac{\partial f(x,z)}{\partial x}dz=\frac{\partial}{\partial x}\int_a^b f(x,z)dz-\frac{\partial b}{\partial x}f(x,b)+\frac{\partial a}{\partial x}f(x,a) \qquad [9]$$

In equation [8], $h=\eta-z_b$ is the total water depth and τ_{sx} and τ_{bx} are the horizontal shear stress acting at the water surface and at the channel bed, respectively. In this problem, τ_{sx} is assumed to be zero.

(7) Show that similar vertical integration of the mass conservation equation leads the following depth-integrated mass-conservation equation.

$$\frac{\partial \eta}{\partial t}+\frac{\partial (Uh)}{\partial x}=0 \qquad [10]$$

(8) Show that the equation [8] becomes equivalent to the following kinematic wave equation [11] under the following assumptions: (i) the change of the total water depth in x-direction is negligibly small compared to the channel bed slope and (ii) the time-derivatives of water level and velocity components are negligibly small relative to the other dominant terms.

$$-i+I_f=0 \qquad [11]$$

Here i and I_f are defined as

$$i=-\frac{\partial z_b}{\partial x} \text{ and } I_f=\frac{\tau_{bx}}{\rho g h} \qquad [12]$$

(9) Introducing the Darcy-Weisbach bottom friction factor, f', the bottom shear stress, τ_{bx}, is defined as

$$\tau_{bx}=\frac{\rho}{2}f'U^2 \qquad [13]$$

Based on equations [11], [12] and [13], show that the depth-averaged velocity, U, is determined by the following equation [14].

$$U = \sqrt{\frac{2igh}{f'}} \qquad [14]$$

(10) In contrast to the assumptions of kinematic wave, let us assume that the magnitude of the horizontal derivative of the water depth is comparable to the slope of channel bed. Under this assumption, equation [8] is simplified to the following diffusion wave equation.

$$\frac{\partial \eta}{\partial x} + I_f = 0 \qquad [15]$$

Relationship between the water surface level and the depth-averaged velocity can be determined through the depth-averaged mass conservation equation [10] and the momentum equation, either [11] or [15], depending on the local conditions such as bed slope and water depth. In practice, on the other hand, *H-Q* curve is often applied for estimation of the flow rate, Q, based on the measured water level, H, which is equivalent to h in this problem. The *H-Q* curve is empirically determined based on the measured data sets of water level H and the flow rate, Q. Assuming that the relationship of the water surface level and the flow velocity is governed by equation [10] and either equation [11] or [15], describe in around 4 to 6 lines how the *H-Q* curve based on [11] differs from the one based on [15] and why these two *H-Q* curves are different. Assume that Darcy-Weisbach's friction factor is constant.

(11) Around the river mouth, river flow is affected by tides and the time-derivatives of water surface level and flow velocity are no longer negligible. Let us assume that the momentum equation of the depth-averaged current velocity around the river mouth is simplified as

$$\frac{\partial U}{\partial t} \doteq -g\frac{\partial \eta}{\partial x} \qquad [16]$$

after deleting all the negligibly small terms of equation [8]. Discuss in around 2 to 3 lines about physical implications of the assumptions made for this simplification.

(12) Assuming that the relationship between the water surface level and the depth-averaged velocity is determined by equations [10] and [16], discuss in around 3 to 6 lines about the characteristics of this relationship. In the discussion, clearly state how the relationship differs from the ones of *H-Q* curves discussed in the previous problem (10).

Problem 2

(1) Figure 2 shows the statistics of flood damage in Japan. Answer the following questions on this figure.

a) Itemize 3 features which Figure 2 indicates.

b) Infer the contributions of changes in society, changes in infrastructure, and civil engineering to those features itemized in the previous question. Describe the inferred contributions in approximately 15 lines in total.

c) Describe a single realistic future scenario which you assume and then describe a future projection of four lines in the figure under your future scenario, in approximately 7 lines. Here, "future" is a term about 50 years from now. The scenario does not need to be the most likely scenario.

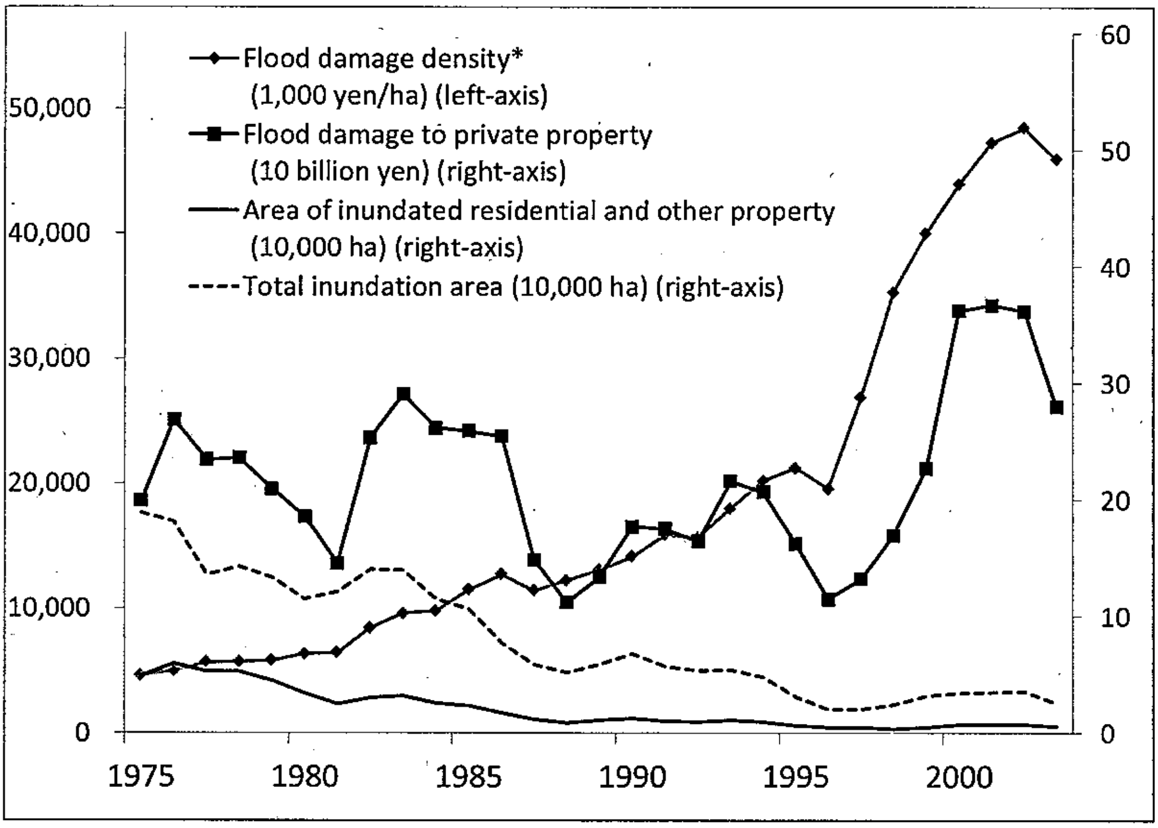

Figure 2: Transition of flood damage in Japan (past 5-year average)
(Source: Modification of White Paper on Land, Infrastructure and Transport in Japan, 2004, http://www.mlit.go.jp/hakusyo/mlit/h16/index.html)

Note: Flood damage to private property and flood damage density include a loss due to business interruption. Damage cost is converted to equivalent monetary value in 1995. *Flood damage density = Flood damage to private property / Area of inundated residential and other property.

(2) A tropical cyclone (later, becoming an extratropical cyclone) in 2012 named as Sandy slammed the East Coast of the US and devastated major cities like New York. See the text related to Sandy given below, and answer the following questions on underlined parts of the text.

a) Describe a single example of "counterproductive" in approximately three lines.

b) What does the author mean by "an integrated and holistic set of solutions, and not put all of our eggs in the barriers"? Describe the answer with examples in approximately seven lines.

Text related to Sandy:

The storm has added new urgency to discussions of adaptation in forums including the New York City Panel on Climate Change, which Bloomberg set up in 2008. Bowman and others have advocated a system of sea barriers or dykes, similar to those constructed in London, the Netherlands and more recently in St Petersburg, Russia. "If we had implemented a regional barrier system, there would have been no significant damdamage" within New York's harbour, he says.

The system envisaged by Bowman and others would include an 8-kilometre-wide barrier approximately 6 metres high that could be opened and closed at the entrance to New York's harbour, and a second barrier at the entrance to Long Island Sound (see 'Surge stoppers'). He puts the cost at around US$15 billion, about the same amount that Congress allocated to the US Army Corps of Engineers in 2005 to build a storm-surge barrier system around New Orleans. Estimates put the damage caused by Sandy at between $30 billion and $50 billion.

Some scientists worry that a single focus on sea barriers could be counterproductive. …

....

"Sandy clearly shows that we have to do the barrier studies now," says Cynthia Rosenzweig, co-chair of the New York climate panel and a senior scientist at NASA's Goddard Institute for Space Studies in New York. "But I think we need to consider an integrated and holistic set of solutions, and not put all of our eggs in the barriers."

(Source: Nature, Vol.491, pp. 167-168, 08 November 2012)

advocate: to publicly say that something should be done
sea barriers: a type of fence or gate that prevents people from high tide water
dyke: a wall or bank / envisage: make the concept of something
counterproductive: achieving the opposite results to the one that you want
integrated: combines many different groups, ideas, or parts in a way that works well
holistic: considering a thing as a whole, rather than as separate parts
solutions: a way of solving a problem or dealing with a difficult situation

Field 4 (Land Policy, Economics, Spatial Information Engineering)

Problem 1

Answer the following questions.

(1) Depict an indifferent curve of a perfect substitute and that of a perfect complement in a case of two goods.

(2) Suppose two infrastructure projects A and B whose (benefit) – (cost) of each year are presented in Table 1. You will select either of them using the cost-benefit analysis. Present that the project selected with Net Present Value (NPV) method is different from that selected with Economic Internal Rate of Return (EIRR) method. Note the social discount rate is 10 percent.

Table 1: (Benefit) – (Cost) of Each Year in Projects A and B

	Project A (Million JPY)	Project B (Million JPY)
Year 0	−10	−20
Year 1	+20	+40
Year 2	+20	+30

(3) A government is planning to construct a huge dam in a small country. Suppose the market price of concrete will increase because the construction of this dam requires a large volume of concrete. Let the market price and demand of concrete before the dam construction be P_0 and X_0; the additional demand of concrete for constructing the dam be $\overline{X}$; and the market price and demand of concrete after the dam construction be P_1 and X_1, respectively. Then present a method to compute the opportunity cost of concrete in this project. Figure and/or diagram can be used if necessary.

(4) Suppose a pure exchange economy with two consumers A, B and two goods $1, 2$. Let the utility functions and the initial endowment vectors of the two consumers be shown as follows:

$$u_A\left(x_A^1, x_A^2\right) = \sqrt{x_A^1} + \sqrt{x_A^2}\ ;\ \mathbf{W}_A = (1,4) \text{ and}$$

$$u_B\left(x_B^1, x_B^2\right) = \sqrt{x_B^1} + \sqrt{x_B^2}\ ;\ \mathbf{W}_B = (2,2)$$

where x_i^j represents the consumption of good j by consumer i and $\mathbf{W}_i = \left(w_i^1, w_i^2\right)$ represents that the consumer i's initial endowments of goods 1, 2 are w_i^1, w_i^2, respectively. When the price of good 1 is equal to 1, compute the price of good 2 that satisfies the Walrasian Equilibrium.

Problem 2

Answer the following questions.

(1) Explain both a geodetic coordinate system and a plane rectangular coordinate system in about 8 lines.

(2) Explain a three-dimensional measurement method with multiple images in about 20 lines by using following words:
parallax, triangulation, orientation, ground control points, pass points.
Figure can be used if necessary.

(3) Explain the difference between Digital Surface Model (DSM) and Digital Terrain Model (DTM) in about 5 lines.

(4) Geometric correction is applied to overlay of satellite images in different coordinate systems. Explain a parameter estimation method of the geometric correction with reference points in about 8 lines, by taking planar projective transformation

$$u = \frac{a_1 x + a_2 y + a_3}{a_7 x + a_8 y + 1}, \quad v = \frac{a_4 x + a_5 y + a_6}{a_7 x + a_8 y + 1}$$

as an example. Where (x, y) are coordinates before correction, (u, v) are coordinates after correction, and $a_1 - a_8$ are parameters.