Entrance Examination for the 2016,

Department of Civil Engineering,

Graduate School of Engineering, the University of Tokyo

Problems of "Civil engineering"

August 31th 2015 (Monday) 13:00 – 16:00 (180 minutes)

(Fields 3, 4, 5 and 6 are not provided in English.)

Please write your answers to problems in two fields which you have selected on questionnaire sheets. <u>If you answer problems in different fields, your answers shall not be marked.</u>

Please use different answer sheets for different problems. 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 hand. 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 sheets, and all answer sheets (including blank sheets or ones for calculation) after the examination.
For Field 7 (Mathematics), please select two problems out of six problems. Please note that special answer sheets are provided for Field 7 and that you cannot use additional answer sheets for Field 7.

Field 1 (Structures)

Problem 1

Consider a horizontal beam which is simply supported at the both ends. The elastic modulus (Young's modulus), the second moment of area, and the span of the beam are denoted by E, I, and L, respectively.

(1) Suppose that the beam is subjected to a vertical concentrated force, P, at the center. Write a boundary value problem for the vertical deflection, w. Here, we take the x-axis along the beam, from the left end at $x = 0$ to the right end at $x = L$. You have to write a differential equation and boundary conditions for the boundary value problem. But you neither have to derive the equation and boundary conditions nor to solve the boundary value problem.

(2) Suppose that a part of the beam is damaged. Model this damage as the decrease in the second moment of area. That is, I, which is a constant, is changed to a function of x. Denoting this new second moment of area by $I(x)$, rewrite the differential equation of the boundary value problem of (1).

(3) Is the distribution of moment of the beam changed after the damage? Answer yes or no first, and then explain the reason briefly.

(4) Is the distribution of the angle of deflection, dw/dx, changed after the damage? Answer yes or no first, and then explain the reason briefly.

Problem 2

Answer the following questions.

(1) Consider seismic responses of a light pole. The damping can be ignored.

a) The light pole is represented as a single degree of freedom system with mass m_1 and stiffness k_1 as in Figure 1. The horizontal displacement of the light pole relative to the ground is denoted as $x_1(t)$. Obtain the equation of motion of this system when the horizontal ground acceleration is $\alpha(t)$.

b) Obtain the response $x_1(t)$ for $t \geq 0$ when the ground acceleration is $\alpha(t) = \sin(\sqrt{1.1}\omega_0 t)$ where $\omega_0 = \sqrt{k_1/m_1}$. The initial conditions are $x_1(0) = 0$ and $\dot{x}_1(0) = 0$.

(2) Consider a two-degree-of-freedom system where the light pole considered in (1) is attached to a bridge modeled by mass m_2 and stiffness k_2 as in Figure 2. $x_1(t)$ and $x_2(t)$ are horizontal displacements of the light pole and the bridge, respectively, relative to the ground. Assume $m_2 = 110m_1$ and $k_2 = 110k_1$. The damping can be ignored.

a) Obtain the equation of motion of this system when the horizontal ground acceleration is $\alpha(t)$.

b) Obtain two natural frequencies of the two-degree-of-freedom system.

c) Consider the light pole displacement relative to the bridge, $x_1(t) - x_2(t)$. Obtain the ratio of the amplitude of this light pole relative displacement to that of the bridge displacement for the first mode.

(3) Describe two ways to suppress seismic responses of accessary structures, which are typified by light poles and traffic sign poles, installed on a bridge, in about two lines each.

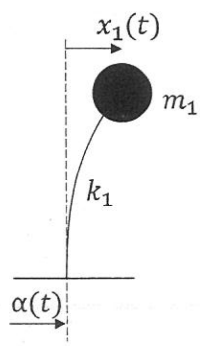

Figure 1 A light pole model

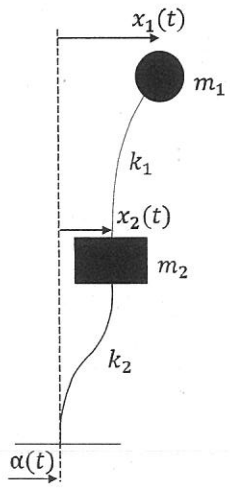

Figure 2 A bridge model with the light pole

Field 2 (Concrete Engineering and Geotechnical Engineering)

Problem 1

Answer the following questions.

(1) Flexural failure capacity of reinforced concrete beam is determined by reinforcement ratio and concrete compressive strength when the size of beam is fixed. Explain how the flexural failure capacity changes by these factors in about 15 lines. For the explanation, you should draw a diagram where the x axis is reinforcement ratio and y axis is flexural failure capacity.

(2) Figure 1 shows a comparison between measured vertical deflection at the span center and corresponding design prediction of a PC (prestressed concrete) continuous rigid frame box girder bridge with a hinge at the center span. Figure 2 shows structural dimensions of the bridge. Departure from the prediction by the linear creep law started a few hundred days after completion of the bridge. The deflection by the linear creep law was calculated by the superposition method with the creep coefficient of 1.58, which was specified in the design code for practice. The concrete compressive strength of 40 MPa, Young's modulus of 35 GPa, relative humidity of 70 %, volume to surface area ratio of 400 mm and drying shrinkage of 185 μ were used in the calculation at design. Answer the following questions.

a) Explain the mechanisms of drying shrinkage of concrete in about 5 lines.

b) Explain the mechanisms of creep of concrete in about 5 lines.

c) Explain the reason why the deflection of this PC bridge greatly exceeded the predicted values in about 8 lines.

(3) Figure 3 shows a removed concrete deck slab of a highway bridge, which was used in a cold mountainous region. Although the location of bridge is far from the ocean, severe deterioration due to rebar corrosion was found.

a) Briefly explain a possible cause of the rebar corrosion.

b) Briefly explain how rebar corrosion influences on structural performance of the concrete deck slab.

c) Explain two countermeasures and their validity to avoid similar deterioration in a new structure each in about 5 lines.

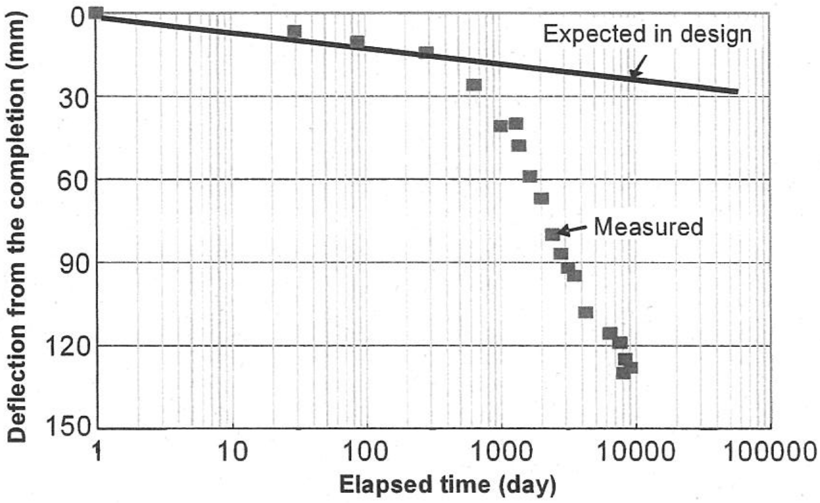

Figure 1

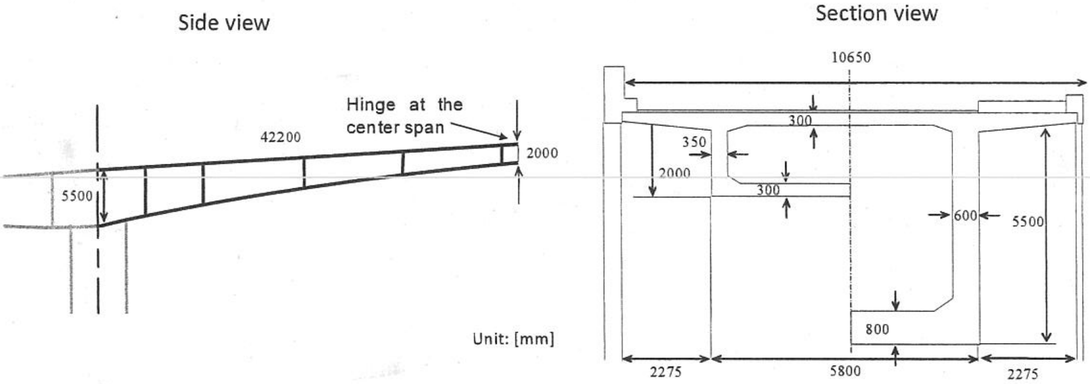

Figure 2

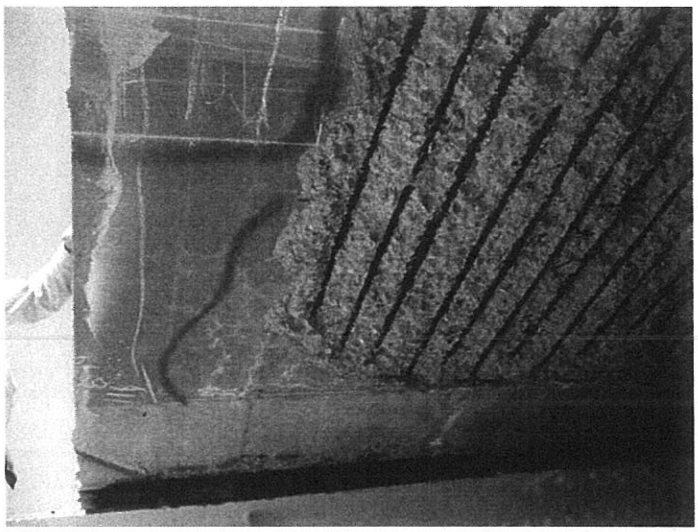

Figure 3

Problem 2

Answer the following questions.

(1) Answer the following questions on consolidation of ground.

a) Explain the mechanism of consolidation in about 8 lines. If needed, schematic figure(s) can be added.

b) List up three countermeasures using different principles that can be applied to a construction work of embankments on normally-consolidated clayey ground. Explain these principles in about 3 lines each.

c) By assuming a case where a pile foundation is constructed in ground undergoing consolidation settlement, explain the matter(s) that requires attention in about 8 lines. If needed, schematic figure(s) can be added.

(2) Answer the following questions on vertical bearing capacity of a spread foundation having a width W=2.0 m that is constructed on ground with a surcharge p=10 kN/m^2. The effect of the self-weight of the subsoil material can be neglected. If needed, set $\sqrt{3} = 1.7$.

a) Illustrate Mohr's circles of stress for the two types of stress state regions as shown in Fig. 4, where the subsoil material in these regions reaches the failure states, exhibiting an internal friction angle ϕ'=30° without any cohesion (c'=0). Under these conditions, calculate the vertical bearing capacity F_1 in kN/m.

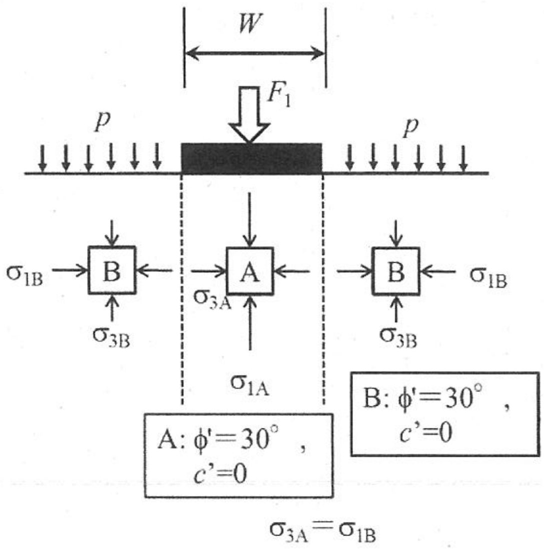

Figure 4

b) Failure of subsoil does not always occur simultaneously, but takes place in a progressive manner starting from the region near the foundation. As shown in Fig. 5, assume that the stress state A is the same failure state as in a), while the stress state B is a pre-failure state which is given as σ_{3B}/σ_{1B}=0.50. Under such conditions, calculate the vertical bearing capacity F_2 in kN/m.

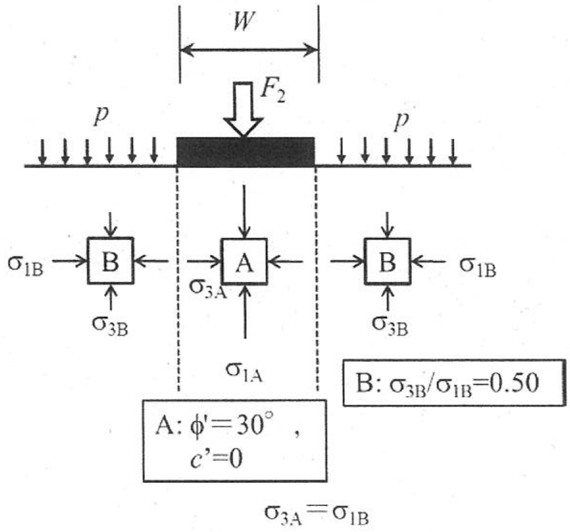

Figure 5

c) Consider another case where the subsoil below the foundation is improved. As shown in Fig. 6, assume that the region with the stress state A reaches failure, exhibiting an internal friction angle ϕ'=30° and a cohesion c'=50 kN/m^2, while the region with the stress state B remains the same pre-failure state as given in b). Under such conditions, illustrate Mohr's circles of stress for these two types of stress state regions, and calculate the vertical bearing capacity F_3 in kN/m.

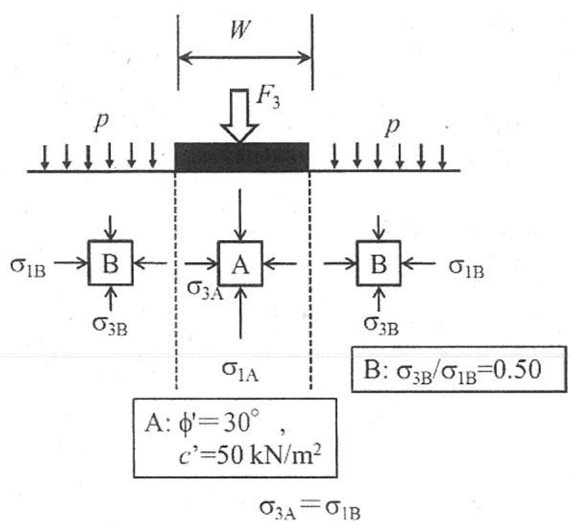

Figure 6