ASSIGNMENT B - APPLICATION OF IRROTATIONAL FLOW MOTION OF IDEAL FLUID TO CIVIL DESIGN ON THE GOLD COAST

Fig. 1 - Photograph of the Gold Coast (Southport beach on 10 June 2002)

Introduction

The assignment deals with the constrution of a new building on the Gold Coast (Fig. 1) and it includes 2 parts : a wind impact study and a groundwater study..

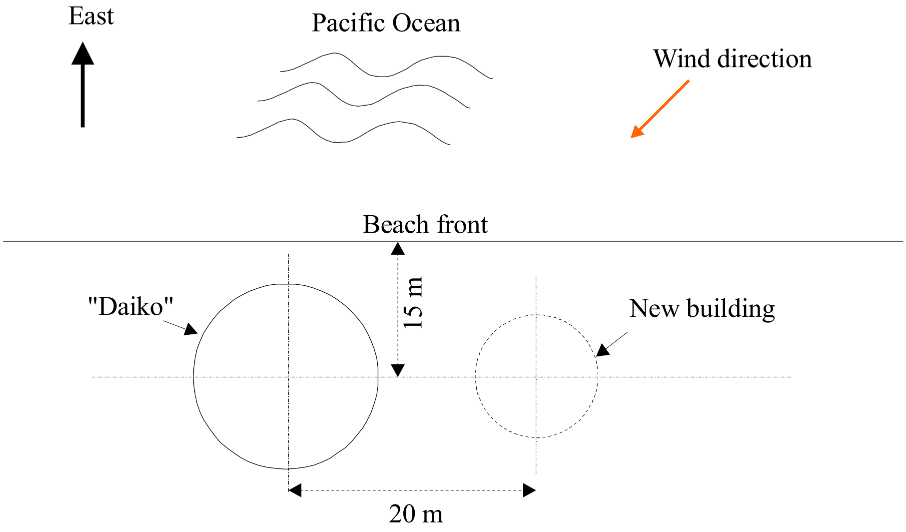
Part 1

You consider the "Daiko" building on the Gold coast (Surfers' Paradise). This a circular cylinder building (Height : 100 m - Diameter : 20 m). The building is in front of the beach facing East (the axis of the building is 15 m West of the beach). Most the winds are South-East wind (Fig. 2).

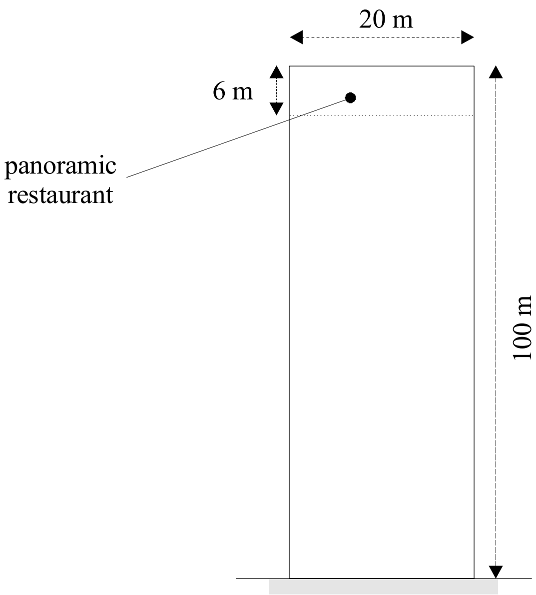
You will assume that the wind flow around the building is a two-dimensional and irrotational flow of ideal fluid. The atmospheric conditions are : $P = P_{atm} = 10^5$ Pa ; T = 20 Celsius.

Fig. 2 - Sketch of the "Daiko" building location

(A) View in elevation



(B) Side in elevation



Part 1A

Flow net

1.1 On a A4 page of graph paper, draw a (top view) sketch of the building, indicate the North, South, East and West as well as the main wind direction. Sketch the beach (15 m East of the centre of the building; Fig. 2), **using the South-East direction as x-axis and the North-East direction as y-axis**. Use the scale 1/200 (i.e. 1 cm = 2 m). Clearly indicate the x-axis and y-axis, their direction and use the centre of the building as the origin of your system of coordinates.

1.2 On graph paper, draw the complete flow net using ten (10) streamlines and the appropriate equipotentials for a **20 m/s South-East wind**. Assuming that the total discharge between two

streamlines is $\Delta Q = 6000$ m^3/s over the height of the building (i.e. 100 m), indicate what value you choose for $\Delta\psi$. Using the scale : 1 cm = 2 m, draw the flow net with the appropriate value of $\Delta\psi$.
1.3 Using the above flow net, determine the wind velocity and the wind direction for people standing on the beach, just in front of the building (15 m East of the centre of the building) ? For SE wind 20 m/s.

Flow pattern
1.4 What standard flow pattern would you use to describe the wind around the building ? What are the main characteristics (Flow, strength, ...) of the resulting flow pattern ? Give the numerical results of these main parameters, in SI units.
1.5 Write the stream function and the velocity potential of the resulting flow pattern. Use this result to compute the velocity components on the beach in front of the building (see question 1.3) and compare your result with the above question. What is the pressure on the beach, assuming that far away on sea, the pressure is atmospheric (i.e. $P_{atm} = 10^5$ Pa)
1.6 What is the expression of the pressure and the velocity at any point at the surface of the building ?
1.7- What is the total lift and drag force on the building. Discuss your results and explain clearly your answer.
1.8 (a) Is the above result realistic ? Why ?
(b) Compute the Reynolds number of such a flow. Is it laminar, turbulent, ... ?
(c) From classical textbook, sketch the most probable flow pattern, for a real fluid, around and behind the building.
(d) Use a text book to estimate of : {d1} the drag coefficient of the building, and {d2} compute the real drag force on the "Daiko" building (for a real fluid flow situation) for a 20 m/s SE wind.
(e) Compare your result with the question 1.7.

<u>Part B :</u>
The top floor of the building (height 6 m - diameter 20 m) is a panoramic restaurant, rotating **clockwise** at a speed of 1 rotation per minute (Fig. 2B). Considering a **20 m/s SE wind** :
1.9 Sketch the flow pattern around the top floor using 4 streamlines;
1.10 what standard flow pattern would you use to describe the wind around the building ? What are the main characteristics (Flow, strength, ...) of the resulting flow pattern ? Give the numerical results of these main parameters, in SI units.
1.11 what is the velocity and the pressure at any point at the surface of the restaurant ? Neglect the effect on the roof of the restaurant.
1.12 is there any stagnation point on the surface of the restaurant ? Why ? In the affirmative, give the location(s) of the stagnation point(s).
1.13 what is the total drag force on the upper level of the building (i.e. the restaurant) ?
1.14 what is the total lift force on the restaurant ?

Part 2

The Gold Coast City Council authorised the construction of a second building next to the Daiko building. The new building will be a 10 m diameter circular tower (100 m height). The axis of the new building will be 15 m West of the beach, and 20 m South of the present "Daiko" building (Fig. 2A).

Part A

Assuming that the ground is 4 meter above the sea level, and that the sea level is constant, you now consider the excavation for the foundation of the new building. The foundations must reach the rock level, 6 m below the surface and the excavation pit must be drained (Fig. 3). A 6 m deep well will be installed to pump the groundwater flow and to reduce the water level in the pit to 0.5 m above the rock level .

You will assume that :

A- the hydraulic conductivity of the ground is $K = 1\ 10^{-5}$ m/s,

B- the water level in the well is 0.5 m above the rock floor (Fig. 3),

C- the ground water table, before the installation of the well was equal to the sea level (i.e. 4 m below the ground surface), and

D- the axis of the circular well is the axis of the new building.

You are required to compute the discharge to be pumped from a 0.5 m diameter well .

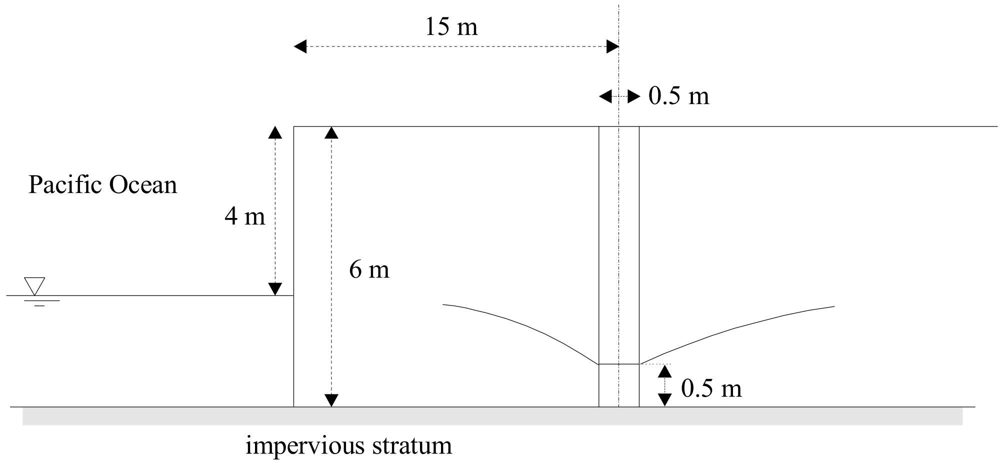
2.1 Sketch, with a scale 1/200 (i.e. 1 cm = 2 m), the piezometric head between the sea and the well and on the West of the well. Sketch a sectional elevation East-West through the well, and a top view with the streamlines and equipotentials.

2.2 Select an appropriate flow pattern and explain, in words, your choice.

2.3 What method would to choose to compute the total discharge Q to be pumped? Explain your method.

You must size the submersible pump to be installed at the bottom of the well. What discharge will be pumped from the well during the excavation work ? Explain your answer in words.

Fig. 3 - Sketch of the excavation works



Part B

You now consider the building itself and for a 20 m/s SE wind you are required to study the interactions between the Daiko building (Part 2A) and the new building (Fig. 2). You will neglect the rotating action of the restaurant at the top of the Daiko building (i.e. no rotating top floor) and you will assume that the wind flow around the buildings is a two-dimensional and irrotational flow of ideal fluid.

The atmospheric conditions are : $P = P_{atm} = 10^5$ Pa ; T = 20 Celsius.

2.4 On graph paper, sketch the flow net (with the two building) for a **20 m/s SE wind**, using 10 streamlines equally spaced 4 m between apart (i.e. 4 m between streamlines in uniform flow). What is the discharge between two streamlines ? **Use the South-East direction as x-axis and the North-East direction as y-axis** ; use the scale 1/200 (i.e. 1 cm = 2 m). Clearly indicate the x-axis and y-axis, their direction and use the centre of the Daiko building as the origin of your system of coordinates.

2.5 Explain what standard flow patterns you would use to describe the flow around these two buildings.

2.6 Write the stream function and the velocity potential as a function of the wind speed V_o (20 m/s) and the two building diameters D_1 (20 m for the Daiko building) and D_2 (10 m for the new building).

The Gold Coast City Council is concerned about the wind velocity between the buildings that may damage cars or knock over people :

2.7 Compute the wind velocity and the pressure at any point on the line joining the axis of the two building. Where is located the point of maximum velocity and minimum pressure and what is the maximum velocity and minimum pressure between the buildings ? Indicate that point on your sketch. Discuss your results. Do you think that this result is realistic ? Why ?

Using the software 2DFlow Plus :

2.8 What is the velocity and the pressure at any point at the surface of the Daiko building ?

2.9 What is the velocity and the pressure at any point at the surface of the new building ?

Solutions

Part 1A

1.1 $\Delta\psi = 60\ m^2/s$ and $V_o = 20\ m/s$ $\Rightarrow$ $\Delta n = 3\ m$ in uniform flow away from the building

At a scale of 1/200, the distance between streamlines far away from the building is 1.5 cm.

1.3 V ~ 24 m/s (graphical solution)

1.4 Doublet : $\mu = 2000\ m^3/s$

1.5 Beach : V = 21.9 m/s and P = 0.995 E+5 Pa

1.8 The flow situation is not realistic for turbulent flow (Re = 2.9 E+7 in this case). For eal fluid flows, the drag on the building is about : Drag = 1.44 E+5 N.

Part 1B

1.10 $\mu = 2000\ m^3/s$ and $K = 65.8\ m^2/s$

1.12 Flow pattern with 2 stagnation points at $\theta = 1.5^o$ and 178.5^o

1.14 Lift = 31.6 E+3 N for all the top floor, ignoring three-dimensional effects at the roof of the building.

Part 2

2.2 Sink + Image Source

2.3 Q ~ 1 E-5 m^3/s

2.6 $\mu_1 = 2000\ m^3/s$ and $\mu_2 = 500\ m^3/s$

2.7 Maximum velocity : 28.9 m/s $\Rightarrow$ P = 0.9974 E+5 Pa