The Institution of Structural Engineers

Possible solution to past AM examination question

Question 4 - April 2009

Bird Hide Structure

by Dr Peter Gardner

Question 4. Bird Hide Structure

Client's requirements

1. An enclosed viewing hide for a bird reserve with enclosed shop/display area below. See Figure Q4.
2. The front and sides are to be constructed with a minimum of obstructions.
3. The interior of the building at level 1 and level 2 is to be obstruction free with a minimum clear height of 2.75m at ground floor level.
4. The internal spaces are not heated.
5. Level 2 is to be accessed via a single external stair.

Imposed loading

6.

Roof	1.0kN/m^2
Level 1 and level 2	4.0kN/m^2
Stairs	4.0kN/m^2

Site conditions

7. The site is level.
8. Basic wind speed 44m/s based on a 3 second gust; the equivalent mean hourly wind speed is 22m/s.
9. Ground conditions:

Ground level – 0.3m	Topsoil
0.3m – 1.0m	Soft clay
Below 1.0m	Firm clay with an allowable bearing capacity of 100kN/m^2

Omit from consideration

10. Detail design of the stair balustrade.

SECTION 1 (30 marks)

a. Prepare a design appraisal with appropriate sketches indicating a viable structural solution for the proposed scheme. Indicate clearly the functional framing, load transfer and stability aspects of the scheme. Justify the reasons for your solution. **(20 marks)**

b. On completion of the design the client asks if a wind turbine could be built on the roof to provide power to the building. Describe the implications this will have on the original design. **(10 marks)**

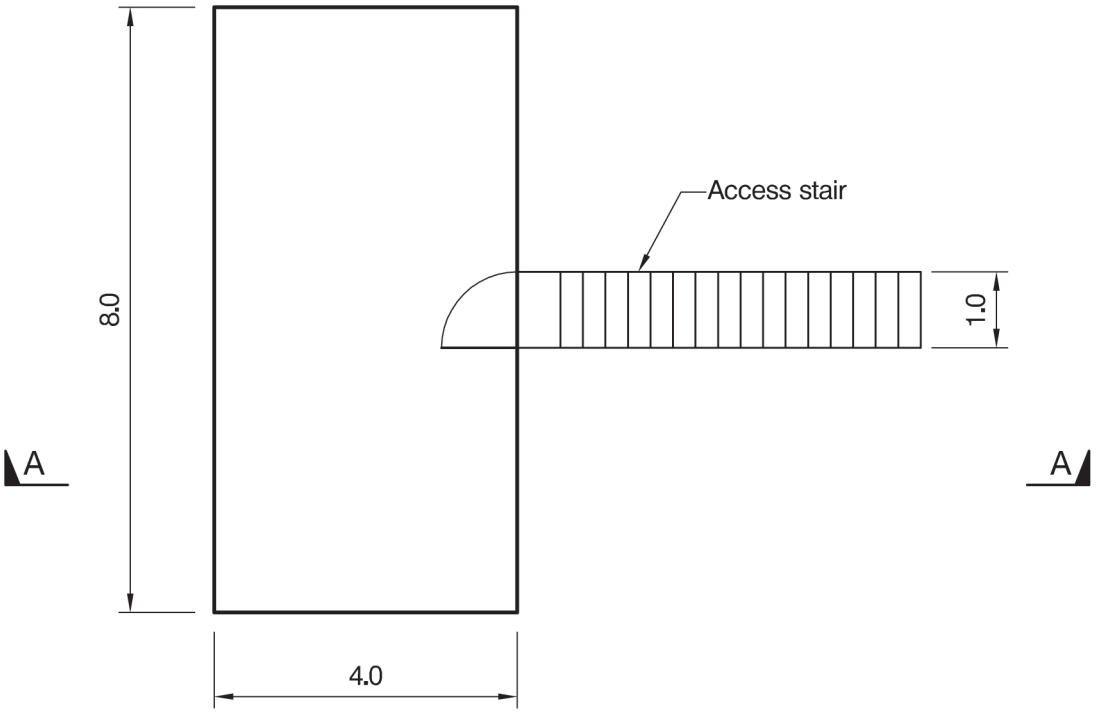
SECTION 2 (70 marks)

For the solution recommended in Section 1(a):

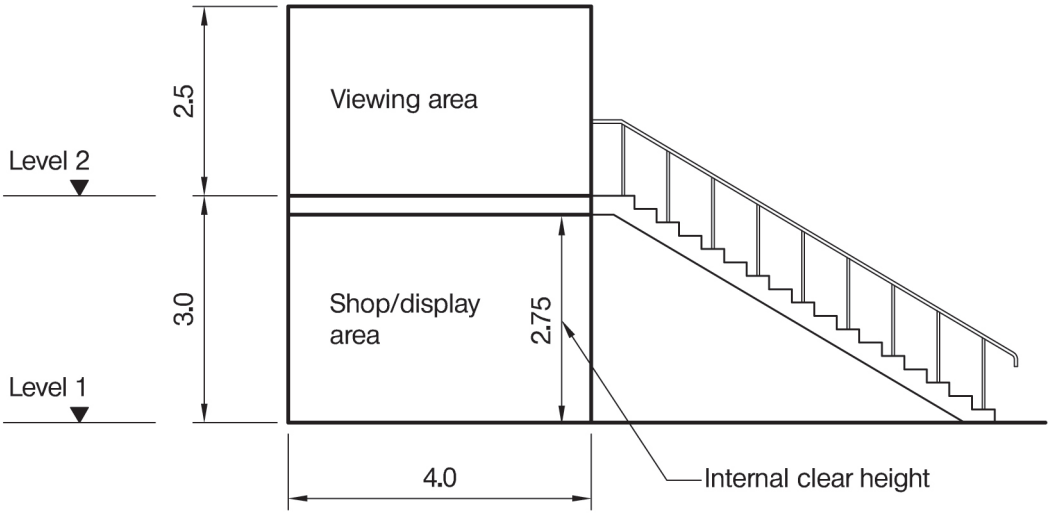
c. Prepare sufficient design calculations to establish the form and size of all principal structural elements including the foundations. **(30 marks)**

d. Prepare general arrangement plans, sections and elevations to show the dimensions, layout and disposition of the structural elements for estimating purposes. Prepare clearly annotated sketches to illustrate details of:
   (i) The junction of the main structure and the foundations
   (ii) The junction of the external wall and the roof **(30 marks)**

e. Prepare a detailed method statement for the safe construction of the building. **(10 marks)**



PLAN



SECTION A-A

NOTE: All dimensions are in metres

FIGURE Q4

Introduction

This is a very straightforward rectangular two-storey structure with some special requirements related to its use (requiring some interpretation) but with no particularly tricky areas. It should therefore provide an ideal vehicle for an experienced candidate to demonstrate their competence across the full range of skills tested by the examination.

The issues

- viewing hide with a shop/display area under
- the front and sides to be constructed with a minimum of obstruction
- interior of both levels to be obstruction free
- a minimum clear height of 2.75 metres to the lower storey
- level two access via an external staircase
- soft clay to one metre, firm clay with a given ground bearing pressure below one metre

Interpretation of the brief

This is, on the surface, a very straightforward two-storey box structure, with modest spans which shouldn't therefore present any particular difficulty. However, the brief is very clear that both levels are to be "obstruction free", which means no internal columns or partitions. With modest spans this shouldn't present any problems. Additionally the brief is equally clear that the front and sides are to be constructed with minimum obstruction, but this requires a little more interpretation. Bearing in mind the structure is in a bird reserve and its purpose is to allow bird watching, it seems reasonable to interpret this to mean a minimum number of columns and no obtrusive stability systems (bracing). Note that the brief says “minimum” not “no obstruction”.

Some candidates find elements of a brief that require interpretation difficult, but actually, in many cases this provides an advantage in that alternative structural arrangements can be discussed, demonstrating your experience and an ability to offer different solutions to varying client requirements. The best candidates usually make full use of the brief and fully embrace the constraints, which are clearly put in questions to provide some challenge (particularly in this question where without the requirement for “minimum obstruction” there would be little or no difficulty). Equally some candidates seem to be determined to ignore the specific client requirements, depriving them of an obvious vehicle to demonstrate their engineering ability, and inevitably losing marks for not fully reflecting the clients' needs.

In this particular question it seems clear that the clients' requirements should be interpreted to mean no internal columns whatsoever, a minimum number of columns on the front and both side elevations and also no obtrusive bracing systems. Although I believe the brief to be clear, a further clue is that the requirement for the minimum obstruction only applies to three elevations, suggesting that something different could be done on the rear elevation. It therefore seems reasonable that a stability system other than straight diagonal bracing should be used in three elevations, external columns should be kept for minimum in the front and two side elevations and external columns should be positioned to accommodate the central access staircase.

It was perhaps surprising that some candidates made no attempt to reduce the number of columns, particularly in the front elevation and seemed quite happy to use diagonal bracing, when there was clearly an alternative (portal bracing, or vertical cantilevers). Some positioned a column right in the centre of the access staircase and others moved the staircase off-centre to accommodate a central column!

Possible solution

The number of external columns on the front elevation will be influenced by the height constraints. The story height is three metres, the clear internal height is 2.7 metres and there is a maximum structural depth of 300 mm (including finishes). A simple span-depth calculation will guide us to an appropriate number of columns. This suggests 4m clear spans, giving columns at each corner, one mid span on the front elevation and two equally spaced to the rear elevation (see figure 1).

An alternative would be to support the level-two floor on the front elevation from a central hanger attached to a deep roof beam. This would provide a completely column-free front elevation for the ground floor shop area.

Stability could be provided by two-storey portal bracing in the front and both side elevations with traditional diagonal bracing in the rear elevation. The level-two floor and the roof could act as diaphragms if constructed from concrete or contain diagonal bracing if timber floors are proposed. A concrete floor and a lightweight roof would seem appropriate. The triangle formed by the rear elevation, stairs and the ground could be used to aid stability in one direction.

The ground conditions are straightforward, with poor ground in the first metre and firm clay with an allowable ground bearing pressure of $100kN/m^2$ at one metre and below. As we are proposing a framed structure, concrete pads constructed on the firm clay would be appropriate. The ground floor slab should be supported on foundations on the firm clay (either on ground beams or perhaps more practically, from strips).

The design calculations should include the access stairs and the portal bracing.

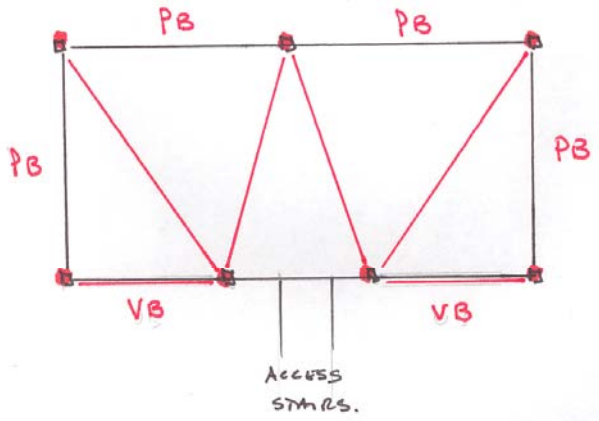
Client change

The scenario presented in part 1b presents a number of issues for discussion. Structurally a wind turbine will present few problems. If we have specified a light-weight roof, then the turbine will require structural support (depending on its exact location), if the roof is concrete then it can be readily accommodated (perhaps with some local strengthening). It would be worth discussing potential variation, especially in relation to the relatively flexible un-braced frame.

The non-structural issue present the greatest dilemmas. The movement and noise associated with a turbine seem inconsistent with a bird hide not-to-mention the possibility of bird strikes!

Summary

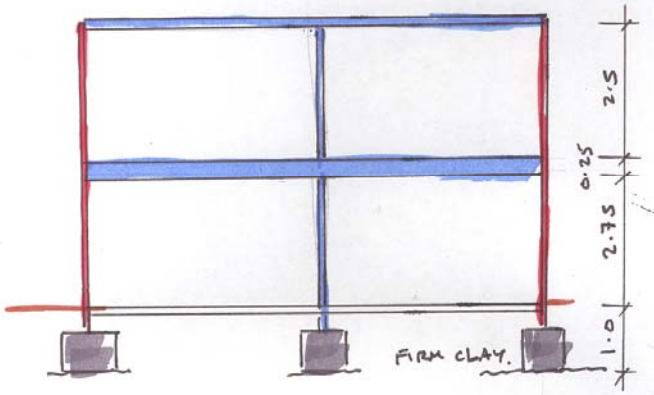
This is a straightforward question, with some interpretation required, particularly in relation to the column layout and spacing. Once this is established the structure is routine, providing an ideal vehicle to demonstrate your knowledge and experience without any insurmountable an hurdles.



PB = PORTAL BRACING,

VB = VERTICAL BRACING.

PLAN

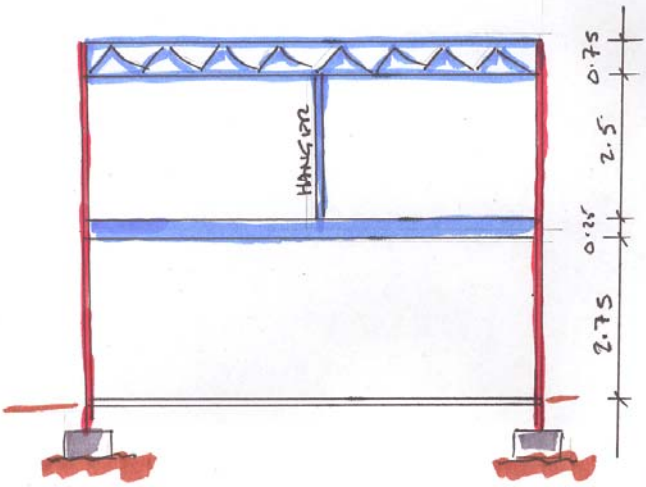


SPAN / DEPTH = SAY 15

∴ 15 × 0.25 = 3.75 m

∴ 4 m SPAN OK.

FRONT ELEVATION



SPAN / DEPTH = SAY 15

8.0 / 15 = 0.533 m

TO LIMIT DEFLECTION

SAY DEPTH = 0.75 m.

ALTERNATIVE

FRONT ELEVATION.

AM. Q4 2009. Figure 1.