Possible solution to past AM examination question

Question 2 - April 2008

Office Building

by Dr Peter Gardner

The information provided should be seen as an interpretation of the brief and a possible solution to a past question offered by an experienced engineer with knowledge of the examiners' expectations (i.e. it's an individual's interpretation of the brief leading to one of a number of possible solutions rather than the definitive "correct" or "model" answer).

Question 2. Office Building

Client's requirements

1. A new four-storey office development. See Figure Q2.
2. The curved elevations are to have full height glazing. The straight elevations are to have brick cladding.
3. Each floor is to have a 2.5m high clear height between floor and ceiling.
4. A single line of internal columns is permitted along the lines AX, BX and CX shown in Figure Q2. Minimum column spacing for internal and external columns is 5 metres centre to centre.
5. Bracing is only permitted in elevations with brickwork. Bracing is not permitted in the office space or in the glazed elevations. Staircases and lifts are outside the building line and structurally independent of the office development.

Imposed Loading

6. Roof $1.0kN/m^2$
   Floor $5.0kN/m^2$
   Imposed loadings include allowances for finishes and services.

Site Conditions

7. The site is level and located in an inland city centre.
8. Basic wind speed is 46m/s based on a 3 second gust; the equivalent mean hourly wind speed is 23m/s.
9. Ground conditions:

Ground level – 0.5m	Top soil
0.5m – 5.0m	Sand and gravel N = 20
Below 5.0m	Stiff clay C = $150kN/m^2$

Ground water was not encountered.

Omit from consideration

10. Detailed consideration of stairs and lift shafts.

SECTION 1 **(35 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. (25 marks)

b. The developer asks if it is possible to locate the columns so as not to be visible on the curved glazed elevations. Explain the effect this will have on the design and outline any resulting changes to your original proposal. (10 marks)

SECTION 2 **(65 marks)**

For the solution recommended in Section 1(a):

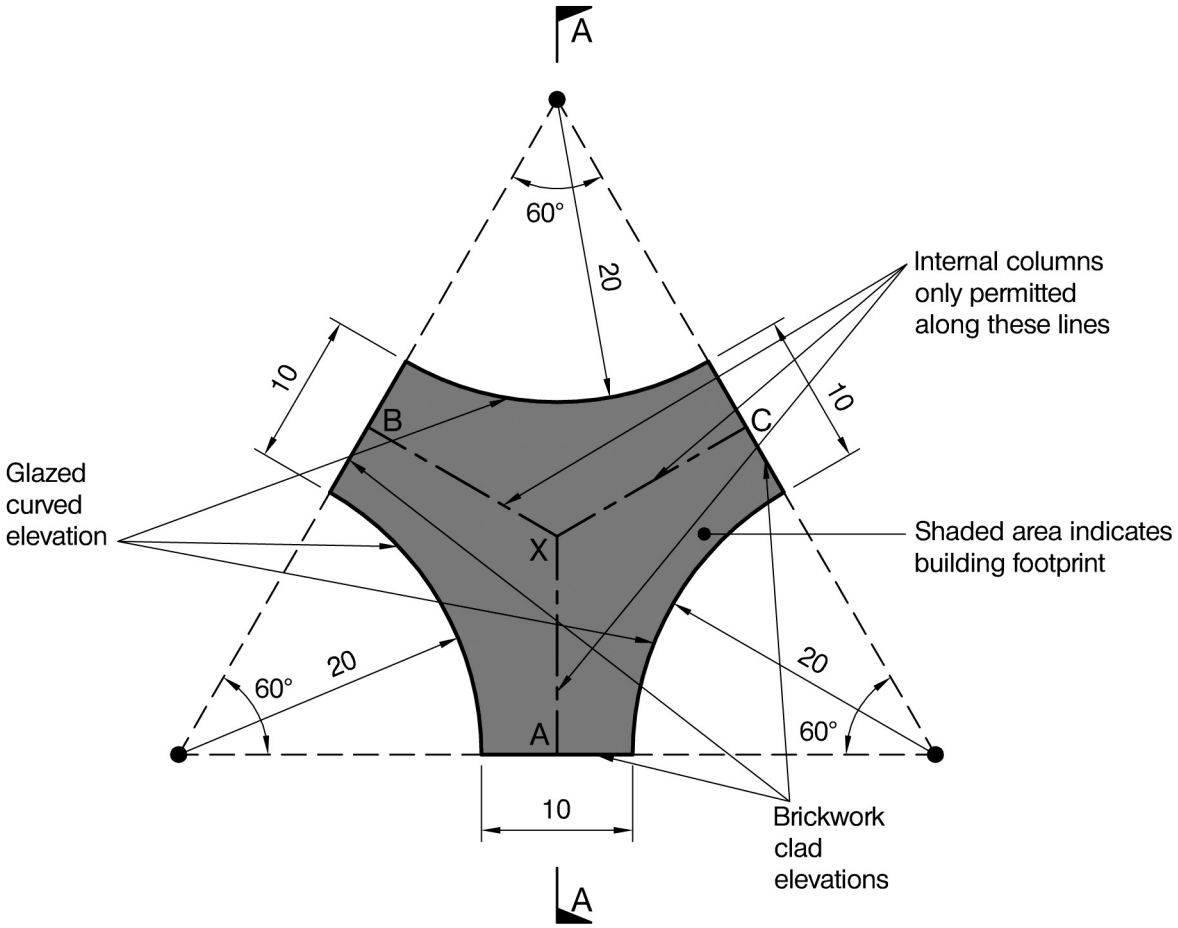
c. Prepare sufficient design calculations to establish the form and size of all principal structural elements including the foundations. (30 marks)

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:

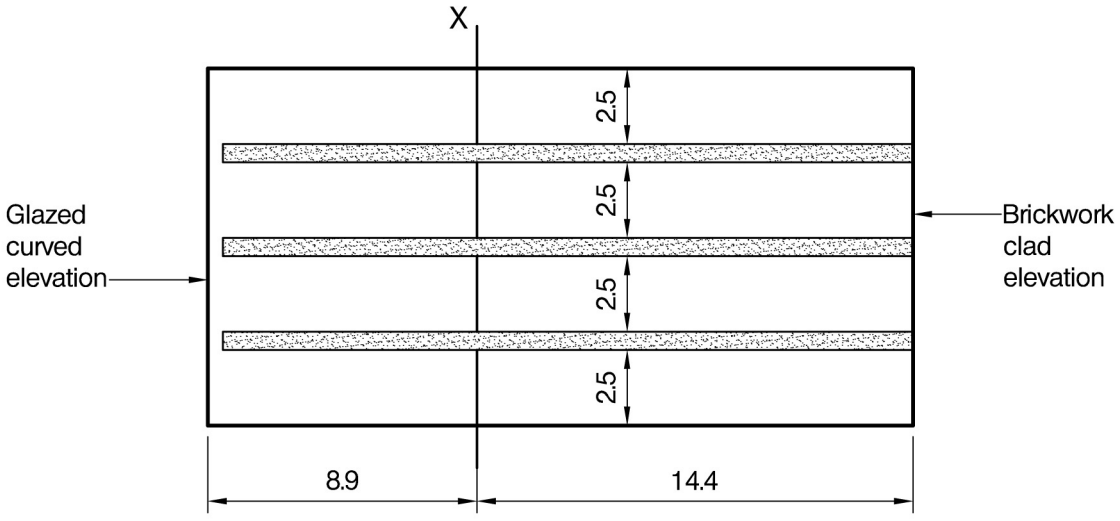
   (i) Connection of a column in the glazed elevation to a floor beam.

   (ii) Connection of the column closest to point X (see Figure Q2) to the adjacent floor beams. (25 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 Q2

Introduction

This question relates to a new four-storey office development, built in a triangular/star shape with three curved elevations and three straight "end" elevations.

It is a relatively straightforward structure other than the unusual geometry and any implications this may have on the structural behaviour (stability).

The issues

- straightforward four-storey office development
- complicated geometry with three fully glazed curved elevations
- three end elevations which are brick clad

- clear floor to ceiling height of 2.5 metres on each floor, but no overall height restriction

- a single line of internal columns is permitted along the three centre lines, the minimum column spacing for internal and external columns is five metres

- bracing is not permitted in the internal spaces or the glazed elevations
- staircases and lift shafts are independent and therefore not able to aid stability
- the straight end elevations can be used for bracing and are clad in brickwork

- the soil profile consists of: topsoil, then sand and gravel for 4.5 metres, below which is a stiff clay with a reasonable ground bearing pressure

Framing, load transfer and stability

As mentioned before, the geometry is really the only complicating factor. The starting point is probably the beam-column layouts, although it is important that the overall approach taken to stability is thought about early on in this question.

Framing

A symmetrical layout utilising the internal columns and appropriately spaced columns around the perimeter (see sketch) should provide a straightforward arrangement for support of the floors and other gravity loads. Reinforced concrete floors spanning between RC or steel beams would be appropriate for a building of this type. The floor could act compositely, or independently (it is probably simpler to assume no composite action for the purposes of this solution). In reality the floor will have a complex behaviour and thus bending moments due its geometry, 3D layout and varying spans. Some basic assumptions will simplify this for analytical purposes.

Stability

As far as the stability is concerned, the restriction in relation to bracing in the glazed elevations provides the challenge. There are basically two options, either using moment resisting frames to resist lateral loads or using the three brick end elevations which can be braced. The shape provides an asymmetry which must be discussed.

The RC floor would automatically act as a diaphragm transferring lateral loads from the glazed elevations to the stability system.

Soil and foundations

The ground conditions probably lead to piles driven into the stiff clay or possibly a raft located one metre below ground level on the sand and gravel.

Presenting a solution

The proposed answer should therefore provide plans and elevations showing the location of the principal elements (columns, beams, floor slabs and stability system) with a commentary discussing each of the parameters in the question (eg floor heights, columns spacings, bracing constraints etc). Additionally it should include sketches showing how the lateral loads are transferred to the proposed stability system and a commentary explaining how the proposal works. Drawings and assessment of the soil conditions with sketches of the resulting foundation system (floor slab, ground beams, pile locations etc) should also be provided.

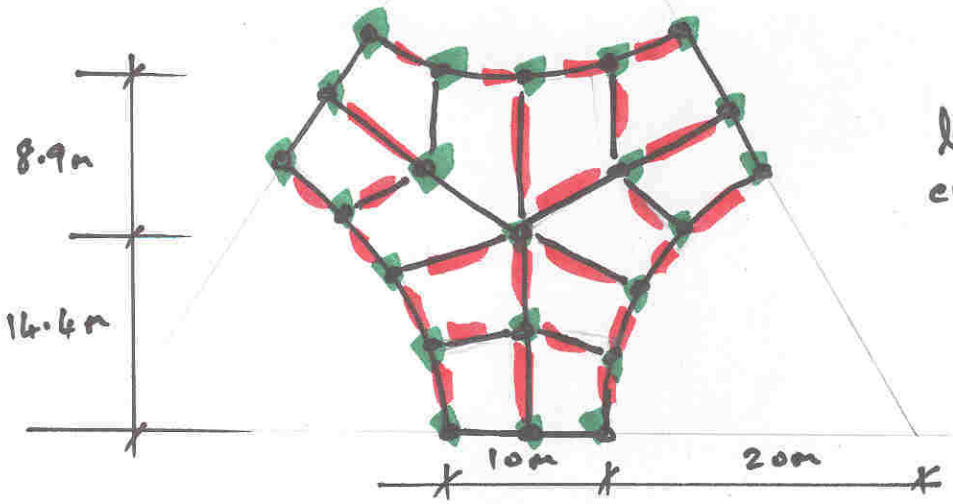
Section 1B

The question provides a scenario where the developer seeks advice on the possibility of locating the external columns away from the glazed facade. The question says “so as not to be visible on the curved elevations” [it says “on” not “from” so this may imply columns could just be moved back from the elevation line]. There are various options which could be explored, ranging from moving the columns back a short distance from the glazing, to eliminating some or all of the external columns but this would necessitate a more complex framing arrangement. This provides an opportunity to discuss various options and the associated structural implications.

Summary

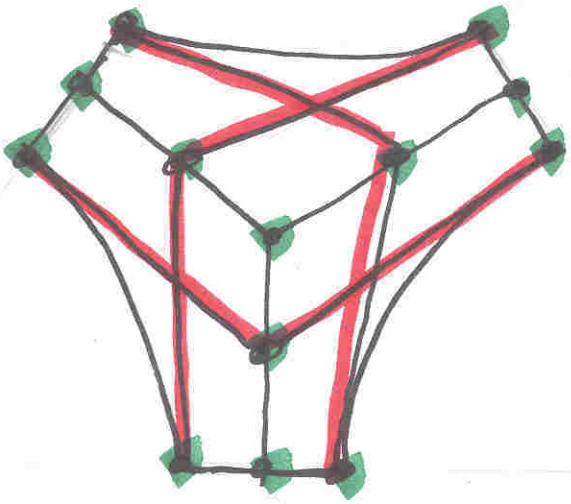
This question involves the design of a relatively straightforward four-storey office development once the geometry has been understood. The only real complexity is understanding the implications of the geometry on any proposed stability system. The question offers an ideal vehicle to discuss various options which in turn enables candidates to demonstrate that they can visualise alternative approaches and articulate the structural advantages and disadvantages.

length from centre
to edge = 16.4m
(thus 2@ 7.2m c/c)



length of
curved elevation
$= \frac{\pi D}{6}$
$= 20.94$ m
(thus 4 @ 5.25m)

BEAM & COLUMN LAYOUT.



REDUCED NUMBER OF COLUMNS - NO EDGE COLUMNS

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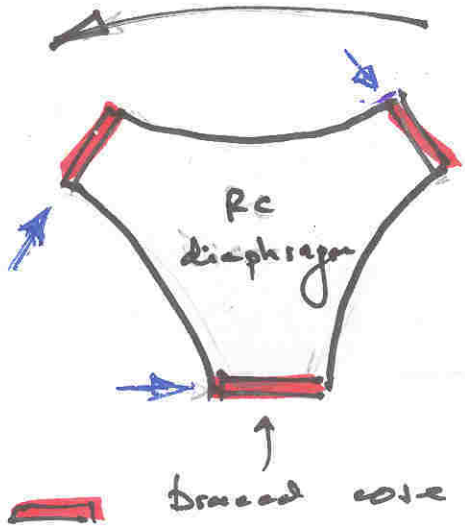
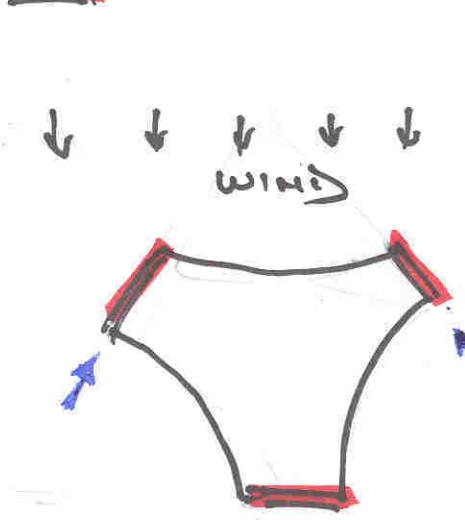
Fig 1 of 2

ROTATIONAL FORCE



WIND

PLAN.

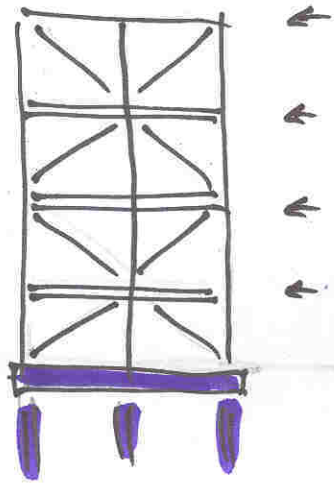


Braced core

WIND

PLAN

Braced core



ELEVATION OF "BRACED END"