The Institution of Structural Engineers

Possible solution to past AM examination question

Question 2 - April 2010

Craft Workshops

by Dr Peter Gardner

Question 2. Craft Workshops

Client's Requirements

1. The owner of a canal requires a new building to accommodate a restaurant, historical display area and 24 workshops. See Figure Q2.
2. The ground floor is to contain the restaurant and historical display area. There will be 12 workshops on the first floor and 12 more on the second floor. Each workshop must provide at least 7.5m by 7.5m of column free space. A central 2m square hatch is required in the first and second floors to allow workshop equipment to be lifted off canal barges.
3. The building spans the canal. The sides of the restaurant and display area facing the canal will be glazed. The number of internal columns at ground floor should be minimised. As much natural lighting as possible is required for the workshops.
4. A clear floor to ceiling height 4.0m is required at each floor. Floors are to incorporate a 500mm deep service zone. No part of the structure shall be higher than 16m above ground level.
5. No foundations or permanent structure are allowed within a 15m wide zone containing the canal and adjacent footpaths. The permanent structure must leave clear headroom of 4m above ground level.
6. The canal must be kept open at all times with 3m high clearance under any temporary works over the full 8m width of the canal.

Imposed Loading

7.

Roof	1.5kN/m^2
Workshop floors	10.0kN/m^2
Ground floor	5.0kN/m^2

In addition the centre of the roof shall be designed for a single 20kN point load in order to allow for lifting equipment through the hatches.
The roof and floor loadings include allowances for finishes, services and partitions.

Site Conditions

8. The site is level and open apart from the canal.
9. Basic wind speed is 50m/s based on a 3 second gust; the equivalent mean hourly wind speed is 25m/s.
10. Ground conditions:

Ground level – 1.0m	Topsoil
1.0m – 10.0m	Firm clay, C = 75kN/m^2
10.0m – 35.0m	Stiff clay, C = 150kN/m^2

The highest recorded ground water level is 0.8m below ground level.

Omit From Consideration

11. Design of the stairs to the workshops.

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. The owner proposes a change to the brief. This requires that all internal columns on the glazed sides of the restaurant and display area between ground and first floor be omitted. Describe how this change could be achieved, using sketches to illustrate your solution. (10 marks)

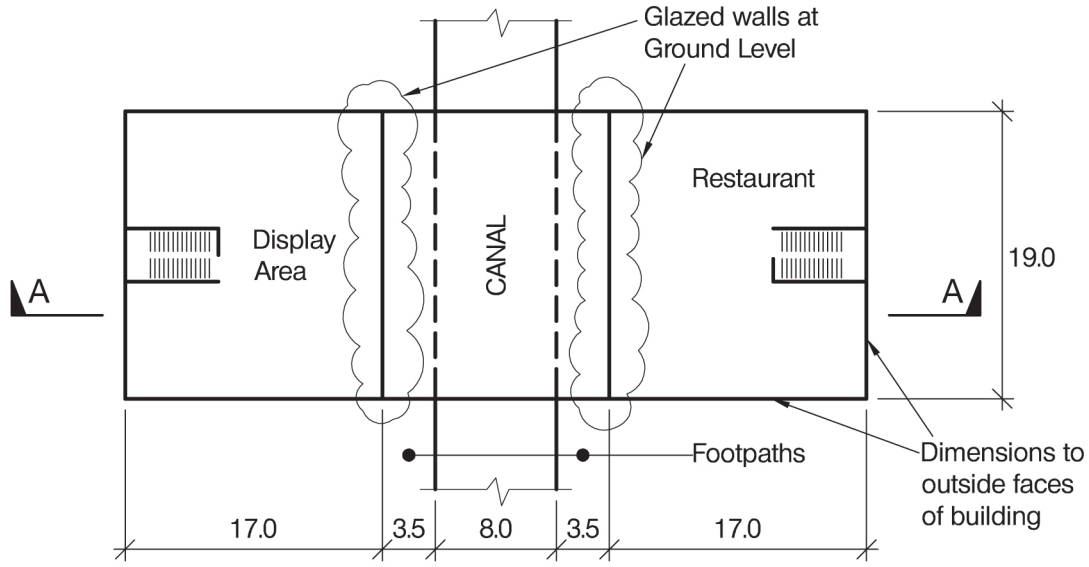
SECTION 2 (70 marks)

For the solution recommended in Section 1(a):

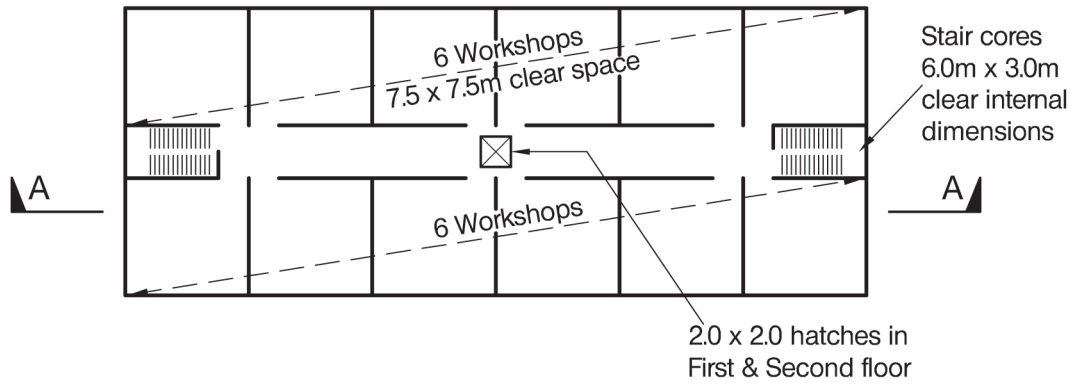
c. Prepare sufficient design calculations to establish the form and size of all principal structural elements including the foundations. (30 marks)

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) A main element of structure spanning across the canal at first floor level.
   (ii) A typical internal foundation, ground floor and column connection at ground floor level. (30 marks)

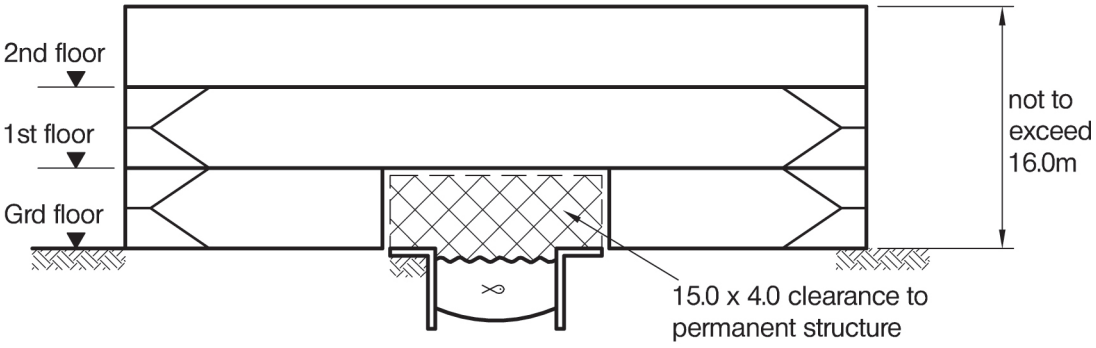
e. Prepare a detailed method statement for the safe construction of the structure focusing on the construction across the canal. (10 marks)



PLAN - GROUND FLOOR



PLAN - FIRST AND SECOND FLOORS



SECTION A-A

NOTE: All dimensions are in metres

FIGURE Q2

Craft Workshops

This question relates to a proposed new building comprising a ground floor with an open area, and first and second floor accommodation comprising 24 rectangular workshops. The structure also needs to facilitate an existing canal and walkway.

The brief is clear, but detailed, and there are some dimensional constraints that need to be fully thought through.

The constraints

- The building spans an existing canal. The elevation adjacent to the canal is glazed.
- The number of internal columns on the ground floor should be minimised.
- The workshops must provide at least 7.5m by 7.5m column-free space.
- A central two-metre square hatch is required for access. There is an associated point load at roof level.
- The workshops require as much natural light as possible.
- A clear floor to ceiling height of four metres is required for each floor. Floors are to incorporate a 500 mm deep service zone.
- The overall structure shall not be higher than 16 metres.
- The foundations (or the permanent structure) must not encroach on the 15 metre wide canal zone. The canal must be kept open at all times.
- The ground conditions comprise one metre of topsoil and a further nine metres of firm clay all sitting on top of stiff clay. As might be expected with the existence of the canal, there is a high groundwater table.
- There are stair cores, which could potentially be used to assist stability.

Implications of the constraints

The starting point for this question should be an assessment of the dimensional constraints, both vertically and horizontally, in relation to the workshops. A sketch would be the clearest and quickest way to do this. This will provide maximum structural sizes for columns/walls and floors and beams (see figure 1). At this point a judgement should be made regarding likely structural members (eg span/depth ratios for floor beams).

The building needs to span 15 metres over the canal, which will require a transfer structure, especially bearing in mind the restricted floor depths and overall height limit. The position of windows, internal doors and the access hatch all influence possible options.

The workshops have a minimum size, which must be contained within the overall building dimensions (this limits wall and column sizes).

The storey heights, structural and services zones all need be accommodated within the overall building height (this limits beam depths).

The workshops obviously require windows that should provide "as much natural light as possible". The elevations overlooking the canal are to be glazed. This does not necessarily preclude bracing, but does necessitate a visually sympathetic approach (is it appropriate to have a large diagonal brace right across a window?).

The brief stipulates that internal columns on the ground floor should be minimised, so clearly some thought should be given to limiting the number of columns without necessarily providing a column free area.

Proposed structural solution

Framing

There are various options for framing and ensuring stability of the structure, including utilising the workshop partition walls to provide structural support and lateral stability. However some form of framing arrangement needs to be provided on the ground floor, principally because of the spans, the absence of structural partitions and the requirement for minimal columns. Additionally a transfer structure will be required over the canal.

Therefore, probably the most straightforward solution is to provide a steel or concrete framed building based on a 8.0m grid, with bracing in the end bays and around the stair cores (see separate section on stability), infill block partitions and a transfer structure to span across the canal.

The requirement for "minimised" internal columns needs interpretation. At the extreme this could mean none, however if this was the intention to question would say "no internal columns". It therefore seems reasonable to provide some internal support at the ground floor level but not simply running columns down beneath each workshop. One column each side in the glazed elevation adjacent to the canal would seem reasonable.

My proposal uses beams at eight major centres supporting the workshop walls above, with columns in the walls forming the upper corridors. Columns in the stair core and canal elevation support a longitudinal beam, itself supporting the first level floor beams (see fig 2).

Transfer structures spanning say 16.0 metres over the canal would pick up the central floor beams and the point load in the roof. There are various possibilities. The windows, and particularly the internal doors, need to be considered (you can have a brace across a window but not a door!). The overall height constraint precludes a roof-level truss but vierendeels, heavy plated girders or storey-height trusses are all possibilities. The critical issue is to ensure that the proposed arrangement can be accommodated in the available structural zones. I have adopted diagonal supports at both first and second floor levels, with different arrangements internally and externally to accommodate the windows and doors (see figure 3). A stainless

steel rod would be more visually acceptable across the window rather than a hot-rolled section (cross bracing may be even better, but is structurally unnecessary).

Stability

There are various options available to provide the structure's stability. The stair enclosures could be used as stiff cores, however they are fairly slender in one direction therefore caution needs to be exercised here. However, if one assumes that the end workshops do not have windows in the side elevation, these two faces could contain bracing, with the cores used to provide longitudinal stability. Each of the floors acts as a diaphragm (a lightweight roof could be stabilized with diagonal bracing). This provides a stable building without needing bracing across the windows, or utilising moment-resisting frames.

Foundations

The strength of the clay needs to be assessed as there is firm clay close to the surface and stiffer material 10 metres down. The brief specifically prohibits any foundation within the 15 metre canal zone. It would not be sensible to move the columns away from the edge of the 15 metre zone, and therefore foundations (whether piles or pads) supporting these columns need to be positioned "off-centre" and designed accordingly.

Part 1b

Section 1b relates to a change in the brief, whereby all [internal] columns on the glazed sides adjacent to the canal are to be omitted.

Your response to this change of brief obviously depends on how you have framed the building in the first place, but essentially some form of transfer structure (a long span beam/truss) spanning 19 metres needs to be proposed. There are various options available including: first floor beams, roof beams with hangers and some form of deep truss/vierendeel utilising the depth of the first floor and/or second floor. Part of the discussion should include options depending on whether or not the client wishes to relax the constraint on the overall building height.

Summary

This is a relatively straightforward question but there are various constraints that introduce some complexity which must be taken into account. There are structural options in all the main areas: framing, spanning the canal and stability system. This gives an ideal vehicle to demonstrate your understanding of structural options and behaviour, and allows you to select the scheme that best suits your skills and experience. A comprehensive answer should provide an opportunity for a good mark.

CRAFT WORKSHOPS.

- Building's overall dimensions 49m x 19m.
- Workshops: 7.5m x 7.5m clear (internal).
- Corridor: 3m wide (assume same as stairs).

Longitudinal.

$49 - (7.5 \times 6) = 4m$ for structural elements

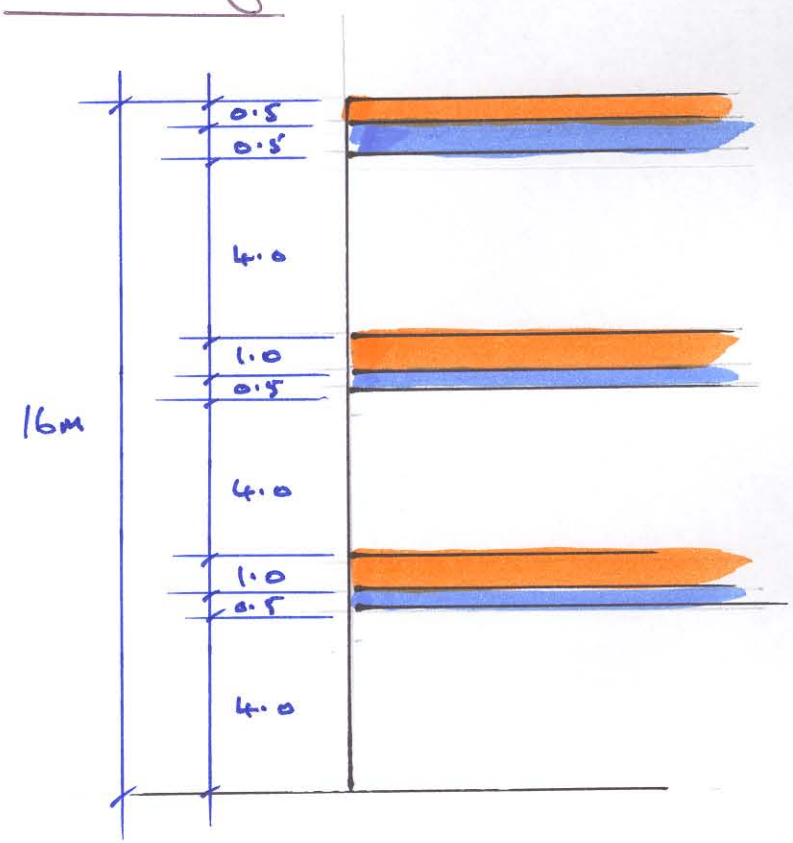
$\therefore 4/7 = 0.57m$ for each partition.

Width.

$19 - (7.5 \times 2) - 3 = 1m.$

$\therefore 1/4 = 0.25m$ for each wall/column.

Vertically.



16m high overall.

4m floor / ceiling.

0.5m service zone.

$\therefore 16 - (3(4+0.5))$

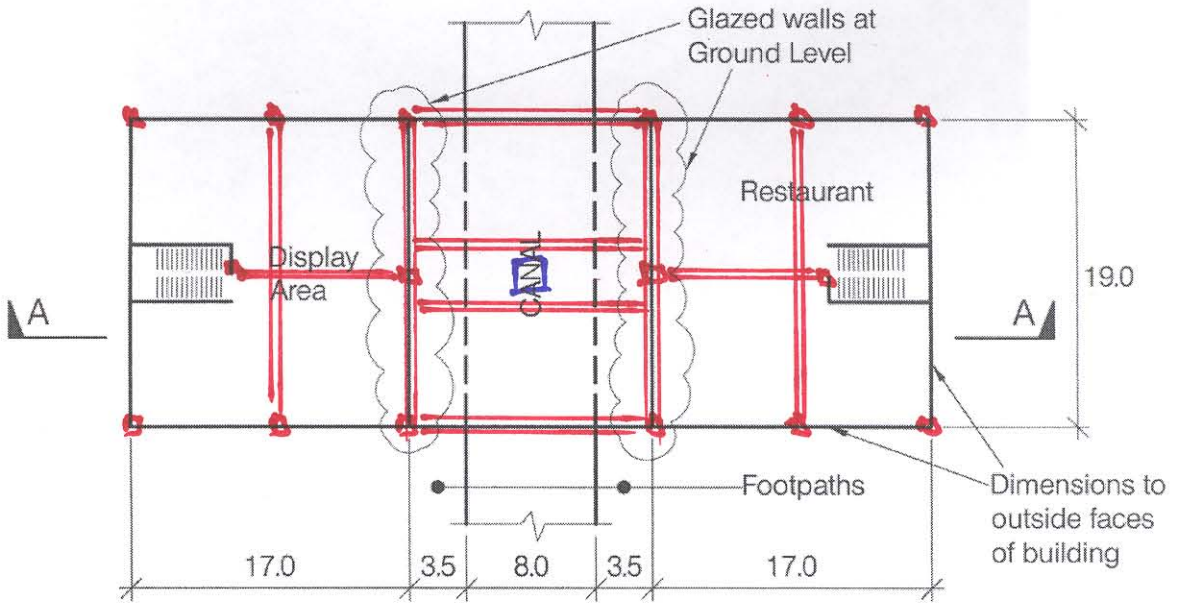
$= 2.5m$ for structure

say:

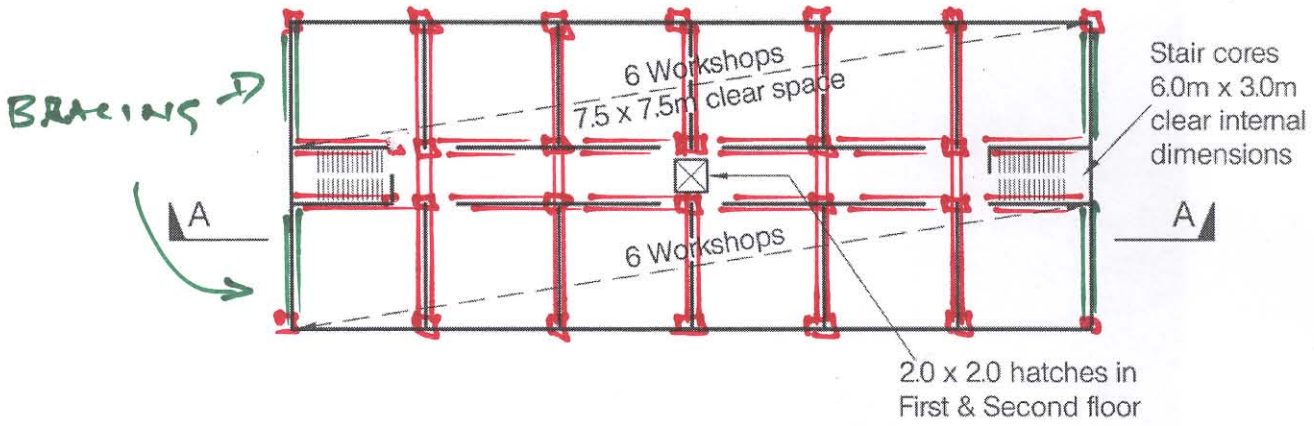
1m for 1st & 2nd floors

0.5m for roof.

FIGURE Q2 - 1.

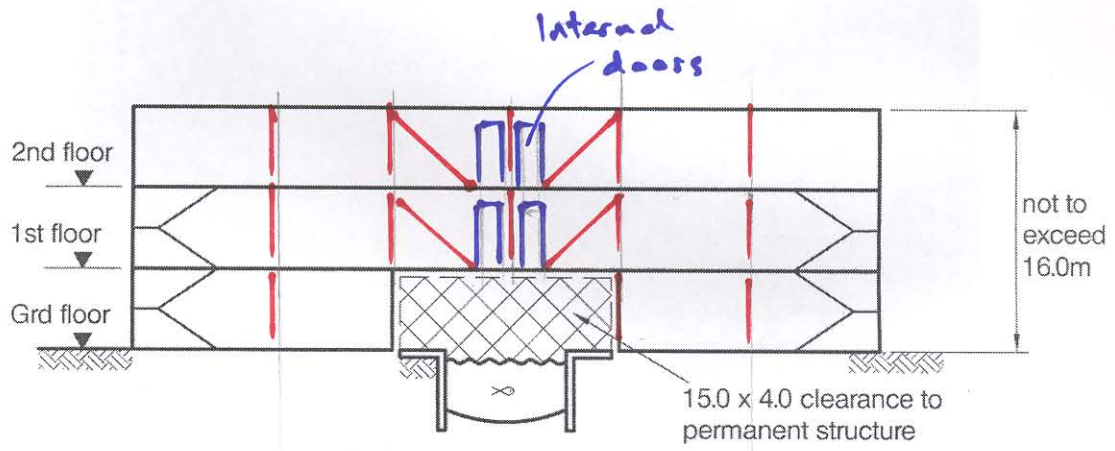


PLAN - FIRST FLOOR

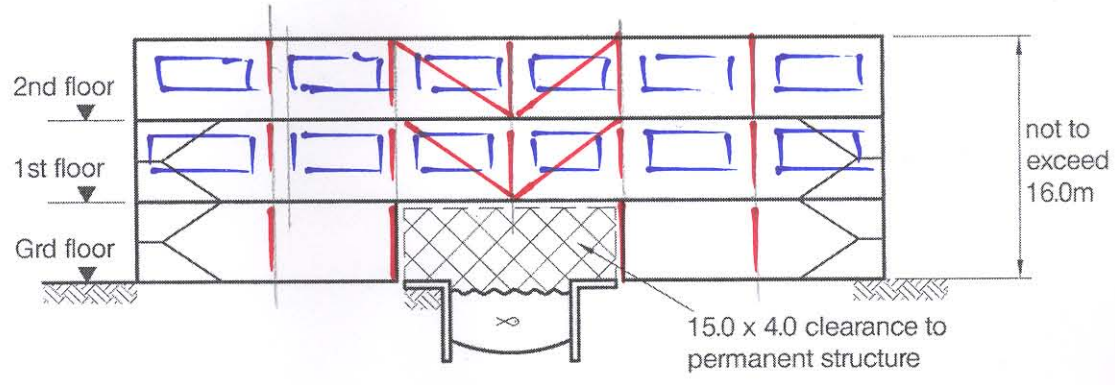


PLAN - SECOND FLOOR

FIG. 2



SECTION A-A



ELEVATION

NOTE: All dimensions are in metres

FIGURE Q2 - 3