Laing O’Rourke is a globally diverse engineering and construction group with a commitment to delivering Excellence Plus performance, founded on 167 years of experience. They fund, design, manufacture, construct and maintain the modern world – providing the buildings and infrastructure to accommodate, educate, employ, transport, care for and sustain communities.

Their business model comprises the full range of engineering, manufacturing, construction and project management services. Their fully integrated offering delivers bespoke solutions to meet the particular requirements of some of the world’s most prestigious public and private organisations. Their collaborative approach combines discipline in delivery with the continuous pursuit of innovation: engaging with customers and partners at the earliest stages, advising on and providing the best ways to complete projects with certainty and achieve greatest value for all stakeholders – employees, customers, communities and shareholders. Their long-term strategy aims to create sustainable growth by meeting the economic, social and environmental challenges of the rapidly changing world.

Their pursuit of engineering excellence is supported by their investment in innovative industry-leading precast concrete and offsite manufacturing facilities.

More information is available online at: www.laingorourke.com.
Introduction

Structural Concrete 2017 sets a demanding challenge for all students studying structural design as part of UK University BEng, MEng and MSc degree courses in Civil and/or Structural Engineering.

This demanding student design competition aims to encourage interest and raise competence in designing with concrete. The competition offers a stimulating and fun challenge to students, while supporting the curricula of civil and structural engineering departments of UK universities. The main benefit for a student is in being able to present their work to prospective employers, some of whom are involved in setting and judging the competition. The national winners will be presented with their prizes at an event in London where their award winning entries will be shown. There will also be a sustainability award for the student who demonstrates the best understanding of this subject in their submission.

These awards reflect a significant commitment from the judges who, together with The Concrete Centre, have carefully developed this year’s competition. Initiative, creativity, aesthetic appreciation and accuracy are called for, and will be assessed by the judges. Above all, this competition has been designed to stretch the technical competence of the students taking part.

Because it is so flexible, Structural Concrete 2017 can easily be incorporated into existing university curricula, with content that reflects an independent project, a group project or a module assessment run over the first, second or both semesters of the academic year.

This year’s challenge…

The 2017 project is theatre-in-the-round set on the banks of a major tidal river in the south east of Britain.

The structure is to provide a new home for a theatre company including stage, seating and all the front-of-house and back-of-house requirements of a theatre. The client, a charity partly funded by the Arts Council and public donations, has commissioned an initial structural design from a firm of consulting engineers. Entrants must respond as if they are part of the consultant’s team.

**theatre-in-the-round**

noun

a form of theatre or theatrical presentation in which the audience is seated around the stage; also known as an arena theatre.
1. Project brief: New Taylor Theatre

The New Taylor Theatre is to be constructed on a brownfield site in the centre of a major city on the banks of a tidal river. The brief requires a theatre-in-the-round with two levels of seating around a central stage area.

The entrance block of the new theatre is to house the reception, box office, bar area, lifts and stairs. The back-of-house area is to provide dressing rooms and storage areas. The project developer has commissioned an initial structural design from a firm of consulting engineers.

The main theatre area is to be located in a regular octagon 40m wide. This comprises the circulation space, stairs and lifts as required to allow easy movement of people, tiered seating, and an area around the stage which can provide flexibility for either additional seating or stage area. The stage area itself is considered a specialist part of the project and the structural engineer is only required to provide a suitable slab to carry the loading. No vertical structure will be allowed in the presentation area so would need to be located either side of the circulation space around the main auditorium. See Figure 1 for the ground floor layout and Figure 2 for the level 2 layout.

The entrance area is to provide all front-of-house amenities. This should include stairs and lifts to levels 1 and 2, reception, box office and bar area. The box office must be located on the ground floor. Toilets are to be located either in the entrance area and/or under the tiered seating. Internal vertical structure should be kept to a minimum in the entrance area.

Two staircases and two lifts should be provided within the circulation space around the auditorium. These are to be located in the areas shown on Figure 2, and need to serve all levels of the theatre and provide adequate fire escape routes.

The back-of-house area is to provide all dressing rooms and washing facilities for the performers on all three levels of the theatre, as well as adequate storage for the theatre. This should include a stair and a goods lift serving all three levels of the theatre.

The roof is to feature a large roof light, 10.5m wide, located over the stage area and octagonal in proportion to the rest of the roof. See Figure 3 for the plan of the roof and Figure 4 showing a cross-section through the building.

The structure is to be reinforced concrete (either in-situ, precast or hybrid concrete construction) and clad in precast concrete. The entrance area is to be clad in glass. The roof light is to be glazed with a lightweight aluminium frame.
2. Design data

Verification of structural viability should be carried out in accordance with current Eurocodes. Entrants should clearly state the documents used in support of calculations. Materials specifications should be defined to current British Standards. Fire resistance of one hour is required.

2.1 Loadings

Dead loads of structural elements: as found.

<table>
<thead>
<tr>
<th>Cladding:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Precast concrete cladding</td>
<td>2.4kN/m²</td>
</tr>
<tr>
<td>Glass cladding and roof light</td>
<td>0.8kN/m²</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Imposed loadings:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Entrance area, circulation space, seating</td>
<td>6.0kN/m²</td>
</tr>
<tr>
<td>Stage area</td>
<td>20.0kN/m²</td>
</tr>
<tr>
<td>Stairs</td>
<td>5.0kN/m²</td>
</tr>
<tr>
<td>Backstage area</td>
<td>5.0kN/m²</td>
</tr>
<tr>
<td>Roof</td>
<td>2.5kN/m²</td>
</tr>
</tbody>
</table>

These loadings include an allowance for services. All values are characteristic values.

2.2 The site

Exposure conditions

The site is flat, and situated in the centre of a city, 10km from the edge of the city.

The value of fundamental basic wind velocity, $V_{b,\text{map}}$, should be taken as 21 m/sec (based on BS EN 1991-1-4:2005). Snow loading may be neglected.

Ground conditions

See borehole logs in the Appendix. Locations of test boreholes are shown on Figure 1.

Ground water level should be taken as 1.0m below ground level.

Figure 1: Ground Floor
LEVEL 2

Figure 2: Level 2

ROOF PLAN

Figure 3: Roof plan

SECTION A-A

Figure 4: Section A-A
## Site Survey & Investigation International

### Borehole Log

<table>
<thead>
<tr>
<th>STRATA</th>
<th>Depth below G.L</th>
<th>Thickness of strata</th>
<th>Type of sample</th>
<th>CKN/m³</th>
<th>0 Deg</th>
<th>m.c %</th>
<th>Density kg/m³</th>
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<tr>
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<tr>
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<td></td>
<td>P</td>
<td>P</td>
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<td>P</td>
<td>160</td>
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## Site Survey & Investigation International

### Borehole Log

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<th>Type of sample</th>
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<th>m.c %</th>
<th>Density kg/m³</th>
<th>'N'</th>
</tr>
</thead>
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<tr>
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<td>P</td>
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<td></td>
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<td></td>
<td>80</td>
</tr>
<tr>
<td>Sandstone, weathered at upper levels</td>
<td>32.3</td>
<td></td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>180</td>
<td>190</td>
</tr>
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</table>

Appendix: Borehole logs
3. Submission requirements

The submission is to comprise four components:

i  A conceptual design report.
ii  Appendix 1 containing design calculations for the selected scheme superstructure.
iii  Appendix 2 containing the drawings of the selected scheme superstructure.
iv  Appendix 3 containing a sustainability appraisal.

The submission must not exceed 60 single sided A4 pages and three A3 size drawings. Only one copy is needed.

3.1 Conceptual design report

A maximum of 30 pages, of either 1.5 line spaced text in a maximum 11pt font, or neatly hand written in black ink, which should include:

i.  An appraisal of two distinct and viable design solutions in structural concrete for the building, together with their associated slab, beam, column, wall and roof layouts. The appraisals should comprise sketches of typical bays with supporting notes, outlining the intended load paths, framing and stability functions, and some brief notes on construction methodology.

ii.  An evaluation of the merits and disadvantages of the two solutions. The evaluation should identify significant differences such as cost or buildability between the two alternatives, and make a recommendation in favour of one solution.

iii.  A description of the foundation scheme adopted for the preferred solution, with a rationale for the selection. A fully detailed design for the foundation scheme is not required.


v.  A method statement for a safe construction procedure for the building.

vi.  A statement of how robustness to avoid disproportionate collapse is satisfied.

vii.  After completion of your design, the client writes to you suggesting that the theatre be changed from octagonal in shape to circular, with a domed roof. Write a letter to the client outlining how this might modify your design.

3.2 Verification of structural viability

The verification of structural viability of the selected scheme should be demonstrated in Appendices to the conceptual design report to make up the balance of the report. (The maximum total length of the design report, sustainability appraisal plus Appendix is 60 pages A4.)

The Appendices should contain sufficient design calculations by hand to establish the form and size of all structural elements for the chosen scheme. Entrants should decide how best to convey this information within the space constraints imposed.

Calculations for individual elements should enable a checker to clearly understand their contribution to the strength and stability of the whole structure, and the load paths assumed. Hence, if computer output is presented, validation by (approximate) hand calculations is also required. Consideration should be given to performance at both Serviceability and Ultimate Limit States.

Note: calculations are not required for stairs, roof light or cladding.

3.3 Drawings

A total of three A3 drawings should be included. Drawings may be prepared using appropriate CAD software, or by hand. In either case, notes and dimensions should not be smaller than the equivalent of an 11pt font.

Two of the A3 drawings should be used to present general arrangements, sections and elevations of the building to show the layout, disposition and dimensions of structural elements for estimation purposes. Drawings should be to an appropriate scale and must be dimensioned. Reinforcement details should not be shown on these two drawings.

The third drawing should show the reinforcement detail at the support of the upper tiered seating; the reinforcement detail at the support of the roof; the detail of the fixing arrangement for a precast concrete cladding panel.

3.4 Sustainability plan

The Client is required to provide a statement to their investors regarding the sustainability aspects of the project. It is important to the investors that the theatre has a long-design life, is low maintenance and is resilient to flooding and climate change impacts.

Prepare a section on the structure to be included in the sustainability statement, including any mitigating measures taken in the specification of the structure, and including sustainability aspects such as fire safety and fabric protection, material efficiency and resilience.
4. Assessment criteria

4.1 Local

The competition will operate at two levels. All submissions made at each university will first be judged locally by the academic tutor(s) involved with the project. The winning submission from each university should be entered for the national level of the competition by the tutor.

Only one entry from each university can go forward for final judging at a national level.

4.2 National

The winning entry from each participating university will be judged at national level using the following generic assessment criteria:

- Compliance with the project brief
- Safety, function, stability and robustness
- Buildability, constructability and maintainability
- Speed of construction and cost effectiveness
- Imagination, flair, aesthetic appreciation and innovation.

The interpretation of the above criteria by the award judging panel will be final and feedback will not be provided.

5. Awards

5.1 University level

The winning entry from each university will receive a prize of £250. The winning entry will go forward to compete at national level.

5.2 National level

The winner(s) of the national competition will receive a certificate(s) and a prize of £1,250. Runner(s) up will also receive a certificate(s) and a prize of £750. The judges may decide on joint prizes in which case the above prize money will be divided up by the judging panel at its discretion.

A special commendation, certificate and prize of £250 will be available for the best Sustainability Appraisal.

The prize-winners’ universities will also receive certificates.

5.3 Presentation

The prizes and certificates will be presented to the winner(s), runner(s) up and winner(s) of the special commendation at an awards ceremony in September 2017 in London. This will be part of a seminar for practising engineers who will be able to review the winning entries. The prize-winners will be notified of further details.

5.4 Eligibility

Structural Concrete 2017 is open only to students studying for a construction-related degree at a UK university. Entries can be single, joint, or from teams of up to four students. Although the competition is aimed at students in their final years of study, entries from any other appropriate undergraduate and/or postgraduate stages will also be considered at the discretion of the academic tutor(s).
6. Rules

I. To enter the competition the university academic tutor(s) should register the university’s intention to participate by emailing The Concrete Centre at info@concretecentre.com. Registration will enable The Concrete Centre to provide supplementary information and/or assistance if needed.

II. The completed entry form naming the local winner should reach The Concrete Centre at either the postal or email address given below by Friday 9 June 2017. On receipt, The Concrete Centre will issue each competitor with an entry reference number.

III. Complete design entries must be received by post, by the final deadline of 4pm on Friday 7 July 2017. The entry reference number should be clearly marked on all items forming the design entry, and on the outside of the package. No other form of identification or distinguishing mark should appear on any part of the submission.

IV. A successful competitor may be required to satisfy the judges that he or she is the bona fide author of the design that he or she has submitted.

V. Competitors should retain the originals of the designs and drawings submitted. The organisers cannot be held responsible for loss or damage to submissions which may occur either in transit or during exhibition, storage or packing. The organisers regret that submissions cannot be returned to candidates after the competition.

VI. Any entry shall be excluded from the competition if:
   • The competitor does not meet the eligibility requirements detailed in Section 5.4
   • The entry is received after the competition closing date in rule III above
   • The competitor discloses his or her identity, or that of the university, in the submission
   • The competitor attempts to influence either directly or indirectly the decision of the award judging panel.

Only one copy of each competitor(s)’ design is to be sent in a single package to:

Structural Concrete 2017
MPA The Concrete Centre
Gillingham House
38-44 Gillingham Street
London
SW1V 1HU
Email: info@concretecentre.com

VII. PDF copies of the drawings from the submission must be emailed to info@concretecentre.com once the entry has been submitted. These will be used to form displays of any winning entries at the award ceremony.
Entry Form

Structural Concrete Student Design Competition 2017

To be submitted by no later than 9 June 2017. This form is to be completed only for the entry which has been marked and selected by the academic tutor(s) for submission to the national competition. Only one entry will be permitted from each university.

<table>
<thead>
<tr>
<th>University</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name and email address of Academic Tutor(s)</td>
</tr>
</tbody>
</table>

The following student or student team will represent the university:

<table>
<thead>
<tr>
<th>Student Name</th>
<th>Home Address</th>
<th>Email</th>
<th>Phone</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
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</tbody>
</table>

1. *I/We have complied with and accepted the rules which apply to this competition
2. *I/We agree to accept the decision of the judges as final, and agree to permit free publication and exhibition of *my/our work
3. *I/we declare that the design is *my/our work and that the drawings have been prepared by *myself/ourselves.
4. *I/we agree that any part of this work may be reproduced in publicity or other materials by The Concrete Centre as required.

*Delete as applicable

Signature student(s): ..........................................................................................................................................................................

Signature academic tutor(s) ........................................................................................................................................................................

This form is to be completed by the competitor(s) and academic tutor(s), placed in a sealed envelope and returned to the address given below. An entry reference number will then be given, which should be marked clearly on all items forming the design entry and on the outside of the package. No other form of identification or distinguishing mark should appear on any part of the submission.

Please return to:
Structural Concrete 2017, The Concrete Centre, Gillingham House, 38-44 Gillingham Street, London SW1V 1HU
or by email to info@concretecentre.com.