Paper

# The Convention Centre, Dublin

Eur.-Ing. **Ken Moriarty,** BSc(Eng), DipStructEng, CEng, MIEI, MIStructE
Director, O'Connor Sutton Cronin & Associates, Consulting Engineers

**Eddie Lyons,** BE, CEng, MIEI, MIStructE
Senior Project Engineer, O'Connor Sutton Cronin & Associates, Consulting Engineers

**Keywords:** Conference centres, Design, Basements, Steel, Frames, Glass, Drums, Temporary works
**Received**: 12/10: **Modified**: 01/11- 04/11; **Accepted**: 04/11
© *Ken Moriarty & Eddie Lyons*

## Synopsis

This paper sets out the various stages, from tendering to completion, of The Convention Centre Dublin (the CCD) project, together with the construction processes involved in each stage. It is located in Spencer Dock, overlooking the River Liffey and was a Public Private Partnership (PPP) project initiated by the Irish State. The PPP company was a joint venture between the Spencer Dock Development Company as developers, Construction Management Partnership (CMP) as design and build contractors and 'The CCD' as operators.

O'Connor Sutton Cronin & Associates Consulting Engineers (OCSC) acted as civil & structural engineers for the project, working directly for the contractor under a design and build contract.

The Convention Centre Dublin was opened to the public in September 2010.

Key milestone dates:

| | |
|---|---|
| Architect first appointed | 1997 |
| OPW tender issued | December 2004 |
| PPP Co. tender submission | May 2005 |
| Preferred bidder appointment | December 2005 |
| Design team tender documents | December 2006 |
| Formal contract signing | April 2007 |
| Start on site (Enabling works) | November 2006 |
| Programme duration (excluding enabling works) | 36+1 mths. |
| Practical completion | 5 May 2010 |
| Services commencement | 5 August 2010 |
| Opening date | 7 September 2010 |

During the height of the design and drawing process, OCSC had 11 full time staff working on the project which included one project director, one specialist structural modelling engineer, four structural project engineers, three general arrangement (structural) draughtsmen and two R.C. detailers. In addition to this there was part time input from the peer review director and also from our structural dynamics expert.

## Client brief

The client brief for The Convention Centre Dublin required a 2000 seat world class auditorium, a 2000 seat banquet hall and a 1200 seat banquet hall, along with numerous meeting rooms and back of house facilities. Due to the constricted size of the site, the three primary function spaces are stacked 'vertically' from an architectural design perspective. From basement level there are two levels of car parking; a 45m × 60m exhibition hall at ground level; a 35m × 47m exhibition hall at first floor level and the 2000 seat auditorium positioned on top with public access from three separate levels.

The client brief also required the building structure to be designed for a 100-year design life for all structural elements, with major replaceable components (cladding) being designed for a 40-year design life.

The exhibition halls are designed for an imposed loading of 12.5kN/m$^2$, the auditorium 7.5kN/m$^2$ and the remaining floors 6.0kN/m$^2$, all in accordance with the brief.

The client tender documents for the project were issued in late 2004. At this point the PPP consortium came together to prepare their bid for the project, which was submitted to the client in May 2005. From reaching preferred bidder status in December 2005, the formal appointment of the successful consortia was made on the 6 April 2007.

Due to the nature of the contract (lump sum/fixed price contract with very high potential LAD's), the brownfield nature of the site and the potential archaeological risks with the site, the design and build consortium elected to commence work on site in November 2006, at its own risk.

## Design discussion

### Site constraints / building layout

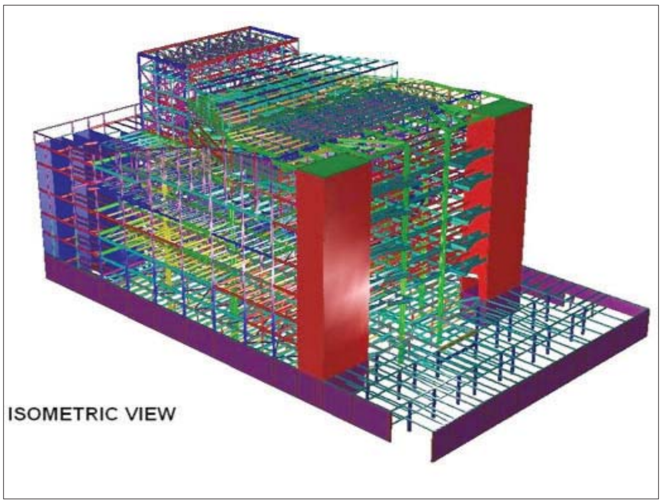
The site, approximately 150m × 75m in plan, was extremely restricted on all its four sides, with a canal under refurbishment to

1 **Aerial view, taken in January 2007, of site plate with secant piling works ©*Peter Barrow Photographers***

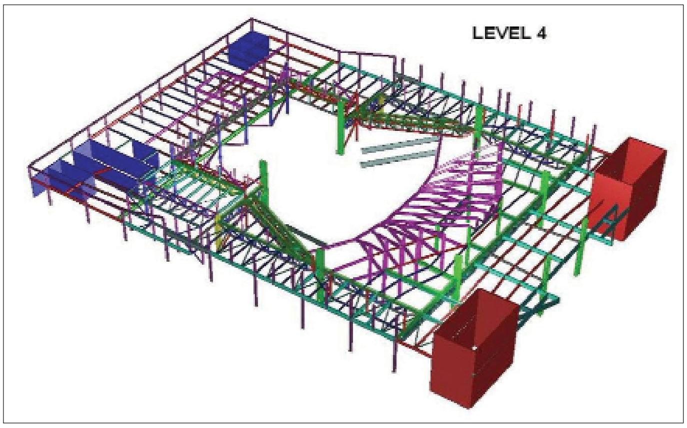
2 **View from office block to the North of the site, showing basement works in September 2007 ©*Peter Barrow Photographers***

3 Aerial view showing basement works and steelwork erection in December 2007 ©*Peter Barrow Photographers*

4 The inside auditorium looking North, showing steelwork erection during August 2008 ©*Peter Barrow Photographers*




5 Isometric view of OCSC 3D Finite Element Analysis model




6 Cut out view of Level 4 from OCSC 3D Finite Element Analysis model

the west, Mayor Street re-construction/Light Rail project under construction to the north, a newly completed office building housing a large corporate tenant to the east and North Wall Quay, a very busy primary traffic route, to the south.

From basement level there are two levels of car parking/double height service corridor and service yard; a 45m × 60m exhibition hall at ground level; a 35m × 47m exhibition hall at first floor level and the 2000 seat auditorium positioned on top with public access from three separate levels.

A 'Van and Truck' lift provides full access from the basement service yard to the Level Two Exhibition Hall and the Level Three Auditorium Stage for a large rigid van and the trailer from a full articulated vehicle.

### Ground conditions / basement design

Ground conditions on the brownfield site varied across its 150m length. To the south of the site the ground conditions could be summarised as:

| | |
|---|---|
| Fill | 0 - 4.0m (m below ground) |
| Soft black silt | 4.0 - 5.5m |
| Fine sandy gravel | 5.5 - 7.0m |
| Soft clayey peaty silt | 7.0 - 13.0m |
| Medium dense coarse gravel | 13.0 - 15.5m |
| Very stiff boulder clay | 15.5 - 21.6m |
| Strong limestone rock | 21.6m |

While to the north of the site the ground conditions were summarised as:

| | |
|---|---|
| Fill | 0 - 4.2m (m below ground) |
| Soft grey silt | 4.2 - 4.7m |
| Medium dense coarse gravel | 4.7 - 7.1m |
| Hard boulder clay | 7.1 - 8.2m |
| Medium dense coarse gravel | 8.2 - 8.5m |
| Very hard boulder clay | 8.5 - 20.8m |
| Strong limestone rock | 20.8m |

Through ground water monitoring the upper level for the ground water level on the site was determined to be *circa* 0.5m o.d, with a design level set at 2.0m o.d.

Due to the variable nature of the ground conditions of the site, it was decided to found the building on continuous flight auger (CFA) concrete piles, of varying diameter. Following a detailed design/cost review of anti flotation anchors, these piles were also utilised as tension piles in both the temporary and permanent works load cases.

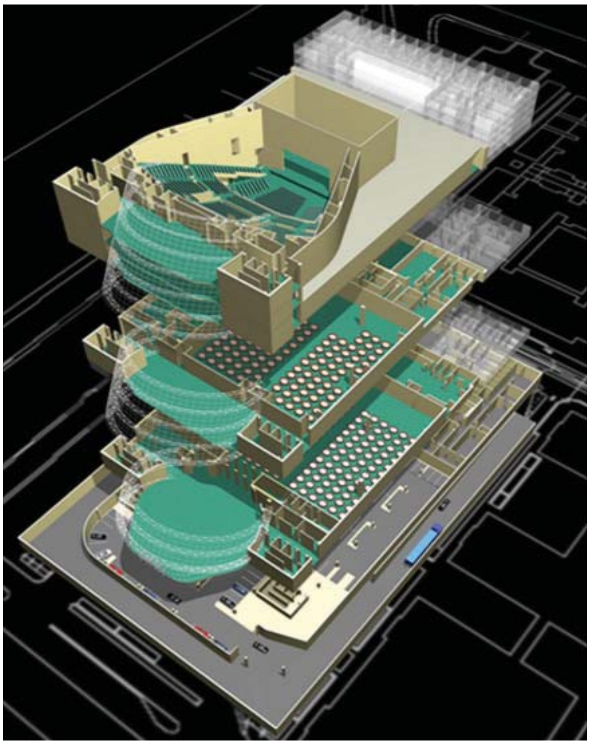
From a design perspective the concrete 'envelope' to the basement structure was specified as 70% ground granulated blast furnace slag (GGBS) concrete. This greatly assisted in achieving The CCD's 'carbon neutral' goal, whilst also meeting the 100-year design life criteria and the requirement to provide resistance to sulphates in the ground.

### Basement construction

In order to construct the two level basement, a 600mm/900mm diameter secant piled wall was formed from ground level around the perimeter of the site (Figs 1, 2, and 3). This wall was constructed to a depth below ground such that the ground water infiltration into the site during the construction of the basement was minimised. The wall was then capped with a structural r.c. capping beam, with the site then excavated to a depth of 7.5m, with only localised ground water de-watering required. Loadbearing 600mm, 900mm and 1050mm diameter CFA piles, using 70% GGBS concrete, were then cast, followed by the part(s) of the basement slab required to form the bases for the two southern concrete cores, which were then jump formed in readiness for early steelwork erection, whilst also providing access for construction workers throughout the project.

### Structural steel analysis / design

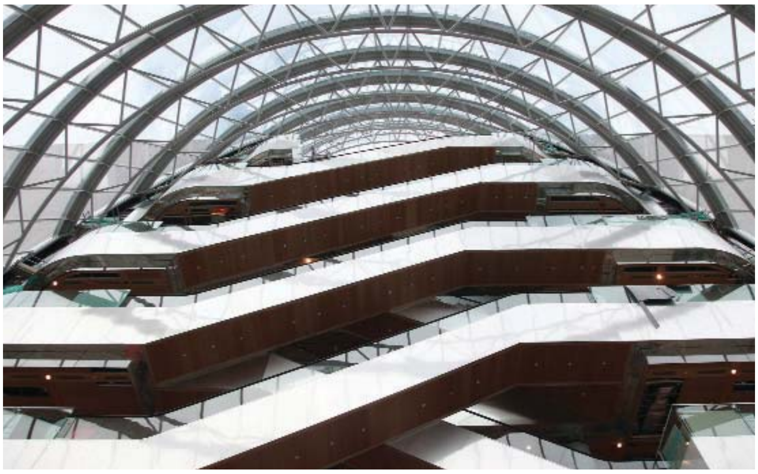
A structural steel solution was chosen primarily because of the



7 Architect 3D impression

8 The Concert Hall auditorium

9 Front elevation of building, during July 2008, showing completed 'drum' structure ©*Peter Barrow*



10 Inside the 'Glass Drum' atrium ©*Peter Barrow Photographers*

long span/shallow structural depth imposed on the project by virtue of meeting the client brief and also keeping within planning constraints for building height, but also for programme reasons insofar as all of the elements were fabricated off site and brought to site in a well managed and controlled sequence.

Due to the location of the auditorium at the top of the building and the requirement for 'column free' spaces in the two exhibition halls, a substantial number of the columns supporting the auditorium seating frames were transferred at the level three floor, through multiple transfer beams and trusses (Fig 4).

The structural stability for the building is derived from the two southern r.c. cores, steel sway frame action of two main frames and also a braced frame on the northern extremity of the building, along the fly-tower elevation. The southern r.c. cores needed to be constructed before steelwork erection began, and they also contain the main escape stairs which provided important access for workers during construction.

The biggest challenge from a design perspective was to determine the dynamic response of the structure to imposed loading, because of the long span/shallow structural depth imposed on the project by virtue of the brief, the planning constraints and the site constraints.

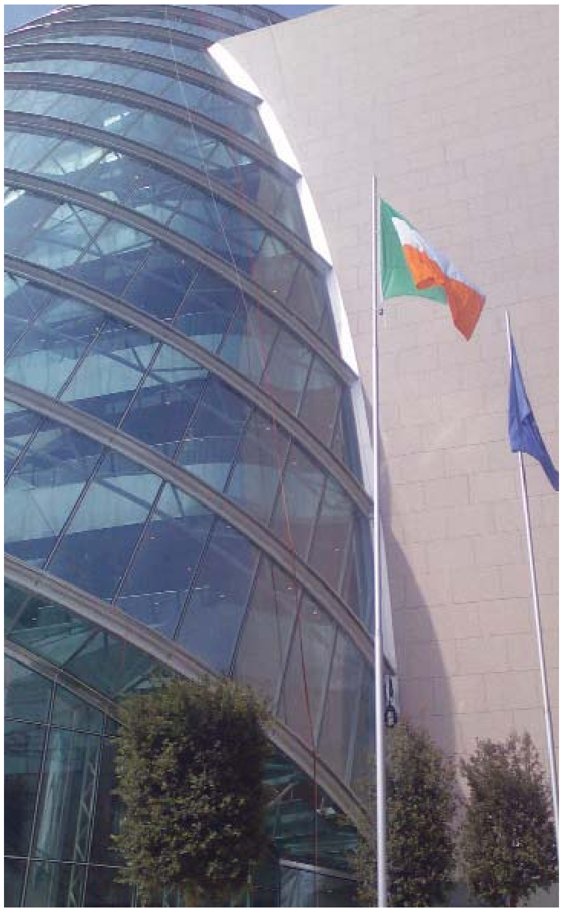
The entire structure of the building was modeled in a three dimensional finite element analysis model to determine this (Figs 5 and 6). The structural frame of the Convention Centre was also then tendered as a 3D model to the steelwork subcontractor as opposed to the more traditional drawing route (Fig 7). This allowed a reduced tendering period, early contractor involvement and aided in the overall iterative engineering the steel frame between the designers and contractors. Additionally, the structural model was used to quickly determine the effect of different structural solutions, thus leading to a highly efficient and cost effective structural solution.

The integration of services into the main structural frame played a big role in the overall steelwork co-ordination/fabrication drawing process. The whole building is highly serviced and the steel frame needed to accommodate all of the building's M&E services whilst staying within the architectural constraints and the client brief.

The structure's steelwork is based around eight internal 800mm × 800mm fabricated plate columns (carrying a maximum load of 40 000kN) with steel trusses (2.3m deep) spanning 22m between columns. Six of these columns extend up through the two exposition halls and top out at the roof level of the auditorium.

The upper auditorium terrace seating is formed using a series of frames which are positioned at 2.5m centres on a radius around the auditorium, each of which have long propped-cantilevers (Fig 8). A number of the columns supporting these frames are transferred out at the Level three floor using trusses which also form the roof of the Level two exposition hall.

11 The South West r.c. core, with temporary crane 'tie-backs' attached – May 2008



12 Completed front elevation, April 2010

13 The Conference Centre from the South Quays ©*Peter Barrow*

Forming the main structural support for the roof over the auditorium is the project's largest single steel element; a 160t, 48m long roof truss. The 6.5m deep truss, consisting of 24 individual pieces, was assembled in position, using two temporary towers to support it until the entire truss was bolted into position with its connecting steel members and secondary trusses.

The 24m clear span (5m clear height) underground service yard, to the north of the site, also incorporates the foundation and transfer structure to accommodate a 35 storey (155m high) privately owned hotel tower overhead. The basement slab under the service yard, at 2.5m thick, was poured in two separate sections, the larger of which is approximately 2375$m^3$. At the time of pouring this it was the largest single concrete pour in Ireland.

### Steelwork erection

Steel erection, which started in late 2007, began on the south side of the site and progressed, in six phases, steadily northwards away from the two southern concrete cores, with an average of two steelwork erection crews working simultaneously. In order to assist in the steelwork erection process, the Level 3 floor slab at mid height of the building was designed to be able to support numerous different types of 'man-lift' cherry pickers, as opposed to utilising heavy mobile craneage throughout the project.

The use of 'Comflor®' metal deck flooring throughout the building minimised the volume of concrete required for the suspended floors, whilst also avoiding the use of temporary propping to floor decking.

### Cladding / glass drum

Aside from the challenging steelwork, The CCD has stone cladding on three elevations supported on a proprietary cladding rail system. With the floor to ceiling heights being so high, the perimeter steelwork incorporates secondary 400mm × 200mm and 350mm × 350mm box sections to support the rail system for the stone cladding.

The front (main entrance) elevation incorporates a 37m span Werner tubular steel glass drum which is effectively hung from the roof structure of The CCD (Figs 9 and 10). The glass drum is the iconic main feature of the building which floods the main foyer with natural light. There are 350 curved glass panels which are 5.2m × 1.5m weighing approximately 600kg.

The steel structure supporting the glass comprises of 10 curved ring beam trusses which are hung from the roof using four, high tension cables. In the temporary works scenario, the drum was supported on two main temporary works towers which were extended in height as the drum was constructed. These towers were removed once the high tension cables were in position and pre-tensioned.

### Temporary works

Temporary works design, normally outside the remit of the project consulting engineer, were taken on board by OCSC for several reasons, namely:

- The fact that OCSC were best placed to carry out the temporary works design, given the fact that the entire structure of the building was modeled in a three dimensional finite element analysis model.
- The tight programme along with potential LAD's in excess of €600k/week meant that OCSC were best placed to carry out the design under the circumstances.
- The nature of the temporary works design requirements was such that in most cases, the critical load cases in design of permanent elements was in fact the temporary works load cases. Interaction with third party design consultants would have added significant additional duration to the programme.

Several examples of the temporary works design are listed as:

- The design of the concrete stair/lift cores to accommodate temporary 'tie backs' from the four tower cranes on the project (Fig11). The cranes were erected firstly as cantilevers from sub-foundation level but they were lifted in height as the building grew in height. To accommodate this, the tower cranes were attached to the r.c. cores via through-bolted steel SHS box section members.

– The critical load case in the design of the cores was the case where the building was fully clad but the cranes were still operational and attached to the cores.
– The design of the level three floor slab to accommodate numerous different types of 'man-lift' cherry pickers which were used by steelwork erection crews to position and connect steelwork elements. This was the critical load case for the design of the slab(s).
– The design of the propping to the ground floor *in situ* podium slab(s) to accommodate mobile cranes, required for the erection of heavy steelwork elements and elements of plant.

As noted previously, the contract was a design and build type contract, where OCSC were employed directly by the design and build contractor. This type of contract, if entered into in the correct frame of mind, can bring huge advantages to both the design & build client and the consultant. In the case of The Convention Centre Dublin, OCSC and the contractor worked very closely together, particularly in terms of the phasing of the basement construction and the steelwork erection, to come up with ways of saving time on the programme by changing, where possible, the design of the structural frame. This would not have been possible on a traditional tendered project.

## Quality control

In addition to OCSC's own internal quality assurance reviews, the contract with the client obliged the d & b contractor to make milestone technical submissions to the client's consultants, prior to the element in question being constructed on site. In practice this involved careful contractor/design team planning and coordination to ensure that the elements in question were given 'Status A' in advance of construction commencing.

In parallel, the funding institution also nominated an independent consulting engineering practice to review the project from a funding 'risk' perspective. OCSC, in conjunction with the d & b contractor, prepared a risk register which outlined the key risks in terms of the design and how these risks were to be mitigated. In addition to and complimenting this, OCSC produced a 'Basis of design' document which set the parameters within which the structural and civil design was to be carried out, how the 100-year design life was to be achieved, design codes to be followed, floor loadings etc.

## Conclusion

The Convention Centre Dublin is the first state-owned, public-access building to be constructed since the foundation of the Irish State. It officially opened to the public on 7 September 2010 (Figs 12 and 13).

It is a benchmark in Irish structural engineering, not only as a result of overcoming the technical challenges presented as a result of placing a full 2000 seater auditorium over two large exhibition halls, but also as a result of the (PPP) contract the construction of the building was executed under and the methods used to tender the substantial steel frame package.

## Acknowledgments

The project team

| | |
|---|---|
| *Client:* | The Office of Public Works (OPW) |
| *PPP Co:* | Spencer Dock Development Company Limited |
| *Operator:* | 'The CCD' |
| *Design & build contractor:* | CMP (a Sisk/Treasury Holdings Joint Venture) |
| *Architect:* | Kevin Roche John Dinkeloo Associates |
| *Structural engineer:* | O'Connor Sutton Cronin & Associates (OCSC) |
| *Services engineer:* | MacArdle McSweeney Associates |
| *Theatre consultant:* | Theatre Projects |
| *Geotechnical consultant*: | Byrne Looby Partners |
| *Steel fabricator:* | Fisher Engineering |