Beacon Hospital
Sandyford, Dublin 18

Beacon Hospital is one of the most recently completed Private Hospitals, based in Sandyford, Dublin. The 22,000m² building offers the very latest in medical treatment, with 8 operating theatres, a full diagnostic department, radiotherapy, ICU/CCU, all supported by ward accommodation of 140 beds.

This paper deals with the structural design and the aspects of constructing the hospital on a confined site against a tight construction programme, particularly focusing on the radiotherapy bunkers, radiology suite and the incorporation of existing structures within the new build.

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Introduction

Beacon Hospital forms part of the Beacon Court development in Sandyford in South Dublin. The hospital is located at the junction of Blackthorn Road and Blackthorn Drive in the Sandyford Industrial Estate. The hospital has 140 beds, with provision for 183 at full capacity. The hospital was developed by Beacon Medical Group (BMG) in conjunction with Johns Hopkins International and Triad Hospitals Inc. and is designed to provide the highest standards of healthcare to both private and public patients.

State-of-the-art systems in Beacon Hospital include MRI, CT scanner with cardiac capabilities, CT Sim, and PET/CT. It features Digital Radiology suites with advanced Mammography, Nuclear Medicine, and Ultrasound, as well as Angiography suites and lab with advanced single-plane and bi-plane systems, and Flouroscopy. There are 8 operating theatres with dedicated rooms for Neurosurgery, Urology, Cardiac, General, Orthopaedic and Ophthalmic Surgery. It has 2 Endoscopy suites, a state of the art Oncology day treatment centre, and therapeutic radiography with LINAC- linear accelerator.

Michael Punch & Partners (MPP) involvement with the site began in 2002, by which stage a number of buildings had already been completed, or were nearing completion. MPP provided civil and structural engineering consultancy for Block O (€5m), the Beacon Aparthotel (€32m), and the Beacon Hospital itself (€98m). This comprised approx. 7,000m² of the overall site area. The architects for the entire development are Traynor O’Toole Partnership, and John Paul Construction had been the contractors for all previous development on the site.
Site

The site for the hospital was originally part of a larger site which was occupied by the Oriflame factory, and was acquired by the client some years previously. Located near to the Sandyford exit to the M50, and near the LUAS, the site was well integrated into the transportation network of the city.

The site, measuring approx. 22,500m², had been developed with offices, a hotel, and a medical clinic, and became known as the Beacon Court development. The site for the hospital was the last available portion of the original site to be developed. In order to increase the available floor space in the hospital to the required 22,000m², the client decided to convert two existing buildings which adjoined the site into hospital use also.
Overview of Structure

The hospital comprises four separate buildings. Two blocks (F and G) were new build. Block H1 was an existing steel-framed building designed for office use, Block O was a concrete-framed building, again designed for office use. While Block O had been designed for hospital loading, Block H1 required significant re-engineering to facilitate hospital use.

Ground Conditions

The site is underlain with granite rock which had to be excavated for the basement. The basement excavation was approx. 7-8m below ground level. The depth of the rock varied from approximately 1.5m to 3.0m BGL, and was highly weathered near the surface in some areas.

The rock was self-supporting when excavated, although since the granite was irregularly fractured. As the basement was excavated, the contractor had his own geologist examine the rock face. Rock anchoring was carried out as required to stabilise areas of the rock face.

The contractor had been working on the site for a number of years prior to the construction of the hospital, and was familiar with the ground conditions, having carried out deeper excavations in some areas in the past.
**Baseline Construction**

The basement is formed by a 450mm thick basement slab, with 2.5m x 2.5m pad thickenings cast integrally with the slab. The basement was tanked externally. A 400mm thick retaining wall was cast with a single-sided shutter against the rock face. The rock face was blinded as required and 50mm insulation was fixed to this.

The basement was designed as a grade 4 structure to the water retaining codes. It was tanked externally with Preprufe membrane, and the rebar design was to BS8007.

**Choice Of Superstructure**

A number of options were examined to determine the most suitable structure for the hospital. This was done in conjunction with the contractor and the design team. These options included concrete beam and precast slab, waffle slab, flat slab and steel frame with precast or metal deck.

Following a cost comparison, the decision was made to proceed with the flat slab design for the following reasons.

- Shallow structural zone required.
- Clear soffit without downstand beams.
- Easier distribution of services below slab.
- Popular with contractors due to speed and simplicity on large areas.
- Inherent fire rating designed in.
- Good acoustic performance.
- Simpler façade to edge fixings than steel.
- Easier to fix pendants etc. to soffit of slab.

*Above:*

1. Precast Concrete Floor Units with RC Frame
2. Insitu Waffle Slab
3. Insitu Flat Slab
4. Steel Beam with Metal Deck.
**Design of Flat Slab**

The flat slab was designed using a Finite Element Method (FEM) program called STRAP. This allowed the engineers to push boundaries of the design of the slab, particularly in relation to the accommodation of opes and risers, which could not be satisfactorily designed using the rules of BS8110 alone.

This is particularly evident for the plant room slab in Block F, which was peppered with holes to allow easier access of ductwork from the plant room to the operating theatres below. This slab also had the additional requirement of supporting the theatre pendants.

The final design for the slab was either a 300mm or 350mm flat slab, depending on the loading conditions. No column heads were required. Shear reinforcement was provided at columns using the Schock system. Bamtec – a roll-out rebar mat system, as used by the contractor to reduce the construction period for the slabs.

The building was stabilised laterally by numerous stair and lift cores.

There was a transfer slab required near the interface with the Beacon Hotel, to allow for a car parking grid to extend under the hospital at lower basement level. The roof slab of the LINAC bunkers also acted as a transfer structure.

The roof is a flat slab with screed to falls, and supports plant areas. The roof over the atrium was constructed with steel beams. The roof cantilevers towards the front of the building, and steel and concrete tapered beams were required to achieve this.
A movement joint is present at one side of the atrium between Blocks F and G. Another was introduced between Blocks H and G, as one being steel framed and the other concrete framed meant that the risk of differential movement was increased.

**Facade**

The façade of the building was a mixture of glass and precast concrete. Creagh concrete supplied the coloured precast panels. These panels were either supported at each floor level, or stacked off a transfer level. The glazing was supplied by Konhauser, and the curtain walling was fixed back to the face of the slab at each floor level.

A glazed atrium connects the main Blocks F and G, and walkways cross the atrium at all levels. The main entrance is located at upper basement level in the atrium.

The atrium consisted of elliptical steel sections spanning horizontally across the space, between two concrete shear walls. At roof level, there was a requirement for full-storey height steel trusses to support the floors, and the elliptical sections were also fixed to these trusses.

**Interfaces with Existing Buildings**

One of the most difficult aspects of the project was the interfaces between the old and the new elements. The hospital design required a seamless linkage, and structurally this meant overhanging or undercutting existing elements, and modifying existing elements, and punching through existing structure with new columns, while maintaining free movement for thermal expansion.

In order to facilitate rapid response and design team interaction, the design team were located on site for the duration of the project. One of the advantages of this was that it was easy to check the existing elements on site, which was a critical part of the process.

**Site Services**

Foul and surface water sewage connections were available at the site boundary near Block O, and sewerage was brought around the front of the hospital to connect at this point.

A 300mm diameter high pressure gas main was located close the site boundary on Blackthorn Avenue, and special precautions had to be taken when working close to the main, as approved by Bord Gais.
A large diameter watermain, which crossed from the public road into the site, had to be diverted away from the site boundary to allow the installation of the sewerage for the hospital.

An extensive programme of roadworks was required on Blackthorn Road, and this formed a separate contract. The programming of sewer and watermain diversions affecting the hospital had to be co-ordinated with the contractors. These roadworks were designed by Faber Maunsell Consulting Engineers.

**LINAC Bunkers**

**Shielding Requirements**

A Linear Accelerator, known as a LINAC, is a high energy-emitting machine used in radiotherapy. A beam of energy can be targeted precisely at tumours to destroy them. The LINAC room must be shielded to prevent the high energy rays from escaping from the treatment room.

The layout of the LINAC area is such as to contain the radioactive particles within a designated area. The walls and roof of the LINAC area must be able to resist the passage of radioactive particles. The treatment room containing the LINAC must have a ‘maze’ between it and the door to the room. This maze is designed to contain the radioactive particles which can bounce between the walls of the room, and by lengthening the path they must take before reaching the exit, the energy of the particles is reduced to safe levels. This was also helped by using a special paint on the walls of the maze.

Ducts through the walls and floor of the bunker had to be limited in size, and angled in a certain way such that the radioactive particles could not escape through them. Air-handling ducts in the ceiling void had to pass through a concrete baffle system – again to avoid a clear passage out of the protective area.

**Shielding System**

The normal way that this is done is by using mass concrete walls and roofs, often up to 2.5m thick. The concrete prevents the high-energy particles from escaping from the room and absorbs the energy from the particles. The ability of the concrete to absorb the energy of the particles is directly proportional to its density – the specified minimum density of the concrete was 2350kg/m3.

The option of using lead blocks to shield the LINAC was considered at an early stage in the project. It was decided that since the LINACs were located under a six-storey building, rather than in a separate single-storey building of their own, that it would be useful to use the bunker as part of the structure of the building. The cost of using lead blocks was also a factor at the time.

The team also examined the option of using magnetite as a heavy aggregate, which would increase the density of the concrete, and therefore reduce the required thickness of the walls. This was ruled out on the basis of supply concerns and cost.
Sizing of the Bunker Elements

The LINAC generates a beam of particles and this beam can be directed in a certain area. Outside this area, the intensity of the beam is lessened. Therefore, the greatest thickness of concrete that is required to stop the particle beam is concentrated over a defined area. The required thicknesses of the bunker elements depended on the amount of radiation directed at them.

The project physicist advised the architect on the required thickness of the various elements of the bunker and the maze. The greatest thickness required was 2.4m, which formed a continuous strip in two adjacent walls and across the roof slab.

The bunkers were located in the basement, and this meant that it was necessary to provide a Grade 4 basement to contain them. A concrete slab and retaining wall was built in the basement, and this was tanked with a Preprufe membrane and designed to BS8007. The bunker walls were then built off this slab.

Plan and section of bunkers, showing concrete pours (top left design, top right actual). Thermocouple locations shown as red dots.
Design Principles

MPP prepared a specification for the construction of the bunkers, and this formed the basis for the contractors work.

Limitation of Crack Widths

For the concrete to form an effective barrier to the radioactive particles, the crack widths in the concrete must be controlled. A radioactive particle can travel through a crack in the concrete. It was agreed with the project physicist that the crack width in the concrete bunkers should be limited to 0.1mm. This is equivalent to the higher standard for water retaining structures.

Thermal gain in large concrete massive concrete structures can lead to very high temperatures being experienced within the concrete section. If there is a high temperature at the core of the section, and a low temperature at the face of the section, then this can lead to cracking within the section.

Since thermal gain was to be minimised, it was important to reduce the cement content as far as possible. The bunker was constructed with grade 30N20 concrete. Ground Granulated Blastfurnace Slag (GGBS), a cement substitute which does not contribute heat to the hydration process, was used as a partial cement replacement, with a 30% substitution rate. The concrete mix was designed by Roadstone and approved by the engineer.

In order to control thermal cracking in the fresh concrete, the temperature difference between the centre of the concrete section and the outside face of the formwork was not permitted to exceed 20°C. If there was a risk that the temperature difference is going to exceed 20°C (i.e. heat is escaping too quickly through the formwork), then more insulation would have to be placed on the formwork.

This meant that the contractor had to measure the temperatures reached throughout the concrete sections over a period of weeks, as well as measuring ambient air temperature during the day and the night. The contractor also had to provide insulated formwork which would reduce the rate of heat transfer between the concrete and the atmosphere.

This requirement lead to longer than normal stripping times for the formwork, as it is still required as an insulating layer when it is no longer required for structural support. Stripping times can be up to six weeks for some elements. This depends on member size, cement content, and ambient temperature.

Minimisation of Construction Joints

Construction joints provide a possible escape route for the radioactive particles through the bunker. In order to prevent this happening, these joints must be detailed in such as way as to maximise the distance that the particle must travel in order to escape. This is done by introducing ‘keys’ into the joint, thereby interrupting the path of the particle through the joint.

In order to maximise the shielding capacity of the bunkers, the number of construction joints was minimised. This meant that the contractor had to organise large concrete pours. Originally we envisaged that the walls would be done in three pours, but this was reduced to a single pour with the agreement of the contractor. This had the benefit of reducing the requirement for joints, and speeding up the construction programme.
The roof slab was poured in two main pours. A stitch pour was done around the edges, which allowed the main pours to shrink slightly before it was completed.

The walls were separated from the basement slab by a slip membrane, and were not structurally connected with rebar. There was a 250mm thick screed cast over the structural floor slab to eliminate the possibility of radiation escaping under the wall.

**Limitation on Reinforcement Quantities**

Another requirement on the concrete bunkers is that excessive rebar must not be used, as this can act as a conduit for some particles which can travel through the rebar at a much faster rate than they can through concrete. Therefore only the minimum amount of steel required to prevent thermal cracking should be used.

The roof of the bunker forms a transfer beam which supports two of the main columns which carry the building overhead. Although the introduction of these loads required a slight increase in the bottom steel in the roof slab, the sheer size of the beam made this increase rather small, and there were no shielding implications.

Note that the starter bars for the columns were tied to the top steel rather than the bottom steel, as the physicist was concerned about the possibility of the particles travelling along the column steel and rising up through the building.

**Avoidance of voids and opes**

It is not permitted to use conventional through-ties in the support of the formwork, as these ties, which hold opposite faces of the shutters together, will remain in the finished wall, and thereby provide a route for the passage of radiation.

**Amendments to Bunker**

Following completion of the bunkers, the physicist required additional shielding of the bunkers in some areas. An additional thickness of concrete was added to three internal wall faces. Metal plates were also required to be fixed to the outside face of the bunkers to enhance its shielding capacity.

**Commissioning**

The bunker tested by the Radiological Protection Institute of Ireland (RPII) for compliance with the regulations, and no problems were noted. The first LINAC began operating in 2007. The second bunker has since been fitted out and the LINAC has been installed. This is expected to be in operation in the coming weeks.
Radiology Suite

The radiology suite is located on the upper basement level of the development. The machines used are MRI, CT Scanner, Fluoroscopy, and X-Ray.

MRI, or Magnetic Resonance Imaging, uses magnetism to generate images of the body by taking slices at defined points. The magnetic field must be contained within the MRI room, so shielding is required. Generally, the walls, floor and ceiling are lined internally with a frame containing a grid of copper strips for this purpose. The structural floor must be dropped to allow this to be fitted.

MRI machines are normally rated as 1.5T (Tesla). However, the next generation of machines are 3T and 5T and these are becoming common in the US now and provide better images. From an engineering perspective, they are heavier, require greater shielding, and have greater steel mass proximity distances than 1.5T machines. The strength of the machine should be established at an early stage in the project.

MRI machines can be heavy, with the magnet weighing 3.5-4.0 tonnes for a 1.5T machine.

There is a restriction on the amount of steel that can be used in the vicinity of the magnet. There are tables published by the manufacturers which stipulate the maximum steel allowable within certain distances of the iso-centre of the magnet (steel mass proximity tables). This needs to be addressed at design stage as it can have big impact on the structure.

In the case of Beacon Hospital, the machine was a 1.5T machine. It was necessary to drop the slab by 150mm in the area of the MRI room to achieve the required minimum distance of the rebar from the iso-centre. The levels were made up using a mass concrete screed with polypropylene fibremesh.

Left - Isogauss Line Plot for a 1.5T MRI machine – courtesy of GE. Right – an MRI.
**Re-Engineering Block H**

Block H is a steel frame building, with UC sections and SHS sections buried within the depth of the floor slab. The floors were constructed with precast hollowcore units, topped with a structural screed. The steel frame was three storeys tall, and was founded on two levels of basement. The basement area was based on a 15.6m clear span car parking grid; therefore, a series of transfer beams were in place at ground level to support the steel frame, which typically had a 7.6m grid. Unlike the superstructure, the basement level was constructed in concrete rather than in steel.

Block H was designed as an office building, and was designed and built prior to Michael Punch & Partners involvement with the Beacon project. The client required that this building be taken into the hospital scheme, and that an additional level be added on top of the existing building. Furthermore, some staircases had to be removed to facilitate the hospital layout.

This process involved a thorough examination of the design of the existing building, which detailed the residual spare capacity, if any, in all of the elements of the building structure. Following on from this, the building had to be redesigned to take an additional load due to the extra floor.

As a result of this exercise, a number of steel beams and columns had to be plated or otherwise strengthened. One of the concrete transfer beams at ground level had to be amended by reducing the span – this was done by introducing an additional steel column to foundation level.
The choice of structure used for the new top level of the building was directly influenced by the structural capacity of the existing building. A series of cellular ‘Westok’ beams spanning 13m across the width of the building, were used. These beams formed the roof of the structure. Plant was to be carried on top of the cellular beams. In order to make the structure as light as possible, a grillage of beams was used to support the plant. This required detailed coordination with the M&E contractor to set out the steel as required by the plant.

Design drawing for additional level to Block H1.
Construction Phase

Introduction

The contract for the construction of Beacon Hospital was awarded to John Paul Construction at the end of July 2004. Enabling works and the main substructure commenced on the 30 August 2004, based initially on an agreement of rates. The final costs were negotiated on the basis of a Guaranteed Maximum Price for the works. The initial contract value for the projects was agreed at €68m, however, during the course of the contract the Client requested that John Paul as Main Contractor would procure and manage the installation of the fixtures, furniture and equipment all within the contract period. This inclusion meant that the final contract sum would rise to €98m.

Programme

The Construction Programme

As part of the initial negotiations a construction programme was proposed was based on an overall duration of 116 weeks (excluding equipment installation). However, the Client felt that the key to the success of the hospital would be the ability to be operational by the end of 2006. On the basis that 3 months would be required to fit out and commission medical equipment prior to this, the construction team was requested to explore all options, with a view to completing the hospital by September 2006.

The only way that significant savings could be made to the original construction programme was to re-evaluate the construction methods, however, with the main structural design of the building well advanced at this stage on the basis of a reinforced concrete frame at this stage; the options were limited.

The final agreed construction programme was based on the use of a number of key construction options:

- The use of ‘Bamtec’ reinforcement in lieu of loose cut and bent steel
- Temporary weathering to the building facades, to enable early progression of the internal fit-out ahead of building weather-tightness
- The use of “Fermacell” partitions in the early stages of the fit-out in lieu of the more usual Gypsum dry-lining systems.
The use of precast concrete units for the erection of the lift cores was also explored; however, the costs outweighed the programme benefit due to the layout.

A final agreed construction duration for the project was agreed at just 104 weeks, a reduction of 12 weeks on the original proposed programme.

**The Equipment Installation**

The agreed programme was based on a 3 month equipment installation period and implementation period commencing on the date of practical completion.

During the latter period of the construction, the Client requested that John Paul Construction assume the responsibility for the procurement, delivery, installation and commissioning of all medical equipment, loose furniture and fixtures. The benefit to the Client was that this could be seamlessly integrated within original construction programme, thus reducing the final training and implementation period.

On completion of the main contract, the hospital was handed over to the Client fully equipped, operational and available to accept patients.

**The Construction Process**

**Ground Conditions**

The site conditions were generally granite rock with throughout, generally self supporting. The trimming of the excavation presented a high risk of collapse, undermining services and the public roads. Rock anchoring was necessary to stabilize the rock face. Anchors were positioned vertically and horizontally at 1m and 2m centres respectively.

The depth of the anchors ranged from 35m to 60m at an inline of 10 degrees.

The rock was not consistent; the elevation along Block G the rock was weathered and as a consequence more friable creating further problems for the support of the excavation. Sheet piles were driven into the weathered rock anchored back by a continuous steel waler.
**Basement Construction**

At occupation of the site, the basement was partially excavated. This had been carried out on the basis of previous plans to construct basement car parking and offices over. The change of use for the site gave rise to higher levels of waterproofing to the basement, thus, increased the wall build-up, which tied into existing car park walls. Therefore, it was necessary to carry out trimming to the existing rock faces bounding onto existing boundaries against the public roads. There was an additional 7,000 tonnes of granite rock excavation also required to accommodate the radiotherapy bunker and the increased floor to floor heights generally.

The substructure construction was typically 2 metres inside the site boundary on 2 sides, with existing buildings to the opposite elevations. The undermining of existing buildings and utilities were the biggest factor of risk, in particular a 300mm diameter transmission gas main located within 2 metres of the excavation. The reinforced concrete structure was formed against a concrete back blinding lined, with insulation and ‘prepruffe’ membrane.

The installation of an anchored ground beam was necessary to retain overburden and the gas main. Furthermore, rock anchoring was necessary to restrain the vertical face of the granite rock excavation.
Radiotherapy Bunker Construction

The construction of radiotherapy bunker required very intense co-ordination and controls to monitor the installation and curing process due to the onerous conditions determined by the design team.

Concrete Design

The concrete design was critical to the construction of the bunkers for the following reasons:

- **Design**-Neutron protection
- **Programme**-Reduction of heat build-up during hydration
- **Installation**-Workability during placement

Ground Granulated Blast Furnace (GGBS) was introduced to extend the hydration process, thus reducing the initial heat gain, and angular limestone with low-shrinkage characteristics. The use of GGBS was designed to reduce the overall temperature build-up by 5 deg. C, and extend the duration from 48 hours to 72 hours to reach the maximum temperature. The design was based on Roadstone’s experience from previous mix designs used in similar applications.

The GGBS also affected the initial set of the concrete, extending the initial setting period by 25% imposing high loads on the formwork for a longer period of time; making the design and construction of the formwork all the more critical.
Formwork Design

After much deliberation the walls to the bunkers and associated maze were poured in one operation, so as to minimize the possibility of shrinkage cracking at day joints. The total heights of the walls are 3.6m, ranging from 800mm to 2500mm in thickness. The design of the mix meant that the shutters would be designed to withstand pressures in excess of 60Kn/m². The formwork was designed by ‘Doka’ using a combination of ‘Doka’ “She-bolts” and ‘push-pull’ props.

Constraints imposed by the Consultant Radiotherapist prevented the use of regular through ties due to the obvious breaches in the wall integrity. It is for this reason that ‘She-bolts’ were used. The ends of the bolts were kept within the reinforcement zone, with removable cones that allowed the local recess to be filled with a non-shrink grout with a high lead content.

The internal faces of the shutters were insulated and lined with plywood and taped to prevent grout loss. The purpose of the insulation was to maintain a consistent temperature throughout, thus controlling the rate of cooling.
The design of the formwork allowed early removal of the formwork whilst leaving the insulation in place, enabling the erection of the formwork to progress to the bunker roof in preparation for pouring once the insulation was stripped.

**Co-ordination of Service Routes**

The co-ordination of the equipment requirements was critical. The selection of the exact piece of equipment was key to ensuring that necessary service routes were agreed between the Consultant Radiologist, the supplier and structural engineer.

The main routes for services were through floor trenches with isolated conduits fed through the walls in strategic positions outside of the main radiation field.

**Installation**

The concrete installation required detailed planning and co-ordination. 440m$^3$ of concrete was required for the walls and 200m$^3$ for the roof slab, poured at a rate of 90m$^3$/hr so as to avoid cold joints forming between layers.

To maintain the delivery rate the concrete needed to be batched from 3 plants. However, the GGBS was only stocked in the Ringsend plant and the crushed limestone in the Tallaght plant. Sufficient material needed to be distributed between 3 plants for batching the quantities required.

The placement of the concrete was carried out using 3 number concrete pumps with 49m booms positioned on the public road. The plant for the concrete pour needed the full extent of the road outside the hospital for the pump and truck manoeuvres, located on the main road into Sandyford Industrial Estate. Application was made to the local authorities for a temporary road closure to facilitate the operation, with the pour completed overnight to minimize any risk of delays due to traffic congestion.
Monitoring the Cooling Process

The risk of temperature differentials across the wall was of concern in relation to the risk of micro shrinkage cracks occurring.

The parameters for temperature control were such that the temperature difference between the centre of the wall and the outside faces shall not exceed 20°C. Strict monitoring was required to ensure that the concrete was not allowed to cool too rapidly.

The monitoring of the temperature was monitored on a 24hour basis using nearly 100 thermocouples located throughout the pour. These were all individually linked to a data logger. The results were transferred into a spreadsheet and issued to the Structural Engineer daily for approval/sign-off.

Despite all the measures taken to reduce the temperature levels in the concrete design, the concrete still reached temperatures of 65°C. The external ambient temperature averaged 4 deg C. As a result it became difficult to maintain the temperature of the outside faces of the walls within the specified parameters. It was necessary in the initial stage to sheet the whole bunker to create a tent, into which hot air was blown to reduce the heat losses through the insulation. The low ambient external temperature due to the time of year meant that a period of 6 weeks elapsed before the temperatures of the core and the outside faces of the wall had dropped sufficiently that the insulation could be removed to allow construction to progress.
**Superstructure**

**Bamtec**

The main superstructure of the building was typically reinforced concrete column and flat slab. The numbers of rising elements in the building, such as stair cases, shear walls and lift cases presented a difficulty in relation to the erection time.

The programme demanded that we pour one full floor level (2,500m²) every 2 weeks. The rising elements were complicated, and access for craneage limited. It was calculated that the rising elements would take between 6 and 7 days to complete, leaving 3 days to complete the floor slabs. The critical trade in all of this was the placement of the floor reinforcement.
The use of “Bamtec” roll-out reinforcement was seen as the solution. This would allow the straight bars to be rolled out quickly and the majority of the time be focused on completing the loose bars.

The Engineers reinforcement design was taken over by Heiton’s who were the suppliers of the material. The overall floor reinforcement design was then broken down and re-designed into a series of overlapping mats consisting of straight reinforcement bars. The overall updated design drawings were then submitted to the engineers for final approval.

The installation, whilst speeding up the floor erection, did have one downfall – it relied heavily on craneage, this impacted on crane time to the rising elements in other areas. However, overall it provided added benefit to the project programme at a cost.

The use of the ‘Bamtec’ ensured that the required turn around on the floors was met. From commencement of reinforcement to completion it would take no more than 3 days based on slab pours in the order of 800-900 m².

The rapid erection of the structure, enable the team to maximize the fit-out duration, which was generally tight. The timber and aluminium curtain glazing was problematic throughout the project, thus making the job all the more challenging. The use of temporary weathering to the building was extensive, and combined with the use of Fermacell partitions the fit-out progressed on programme, with out risk of bacterial growth to partitions due to dampness.
The M&E services within the building are some of the most advanced in the country, providing the backbone to equipment systems such as Pyxis, electronic radiology imaging, radiotherapy.

Conclusion

The clients’ expectations were to have a state-of-the-art hospital fully equipped with the very latest medical equipment, allowing them to be at the forefront of medical care.

The delivery of a fully equipped and commissioned hospital within the initial construction programme was a key requirement of the client, offering the ability to commence patient treatment immediately.

The project began on site in August 2004. Practical completion was achieved in September 2006, and the hospital opened for business in 2007. The construction period of 24 months was achieved despite the many difficulties that the project team encountered. Typically, these obstacles would include:

- A tight, brown-field site,
- Conversion of existing buildings,
- The necessarily slow construction of radiotherapy bunkers underneath one of the main buildings,
- Traffic restrictions,
- Services diversions, etc.
The completion date for the project, driven by the commercial pressures of the private healthcare industry, meant that much of the design of the hospital was running in parallel with the construction, and the design team often found that they were only one step ahead of the contractor.

The close co-operation of the client, design team, main contractor and specialist sub-contractors and suppliers, and the extraordinary effort that was put in by all ensured that the goal was achieved. The public recognition of this world-class facility is testament to this.

**Acknowledgements**

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