Above: Finished structure showing a 40-tonne door hung within a 1–2mm verticality tolerance.

The Radiographic Cell

POOLE

Tight temperature controls and a careful mix design ensured the successful build of a concrete radiographic testing cell in Poole, Dorset. Due to an ever-expanding workload requiring a new manufacturing building, the client required the capability to carry out all non-destructive testing in a specially designed on-site radiographic cell, with two bays, capable of handling the new order book 24 hours a day, instead of the previous arrangement of sending completed units off-site or night closure testing on-site.

Structural engineers Julian Calcinotto and Matt Singleton from Calcinotto & Associates were tasked with developing a robust design to enable the construction of a radiographic enclosure with two bays, internal cranage and specially detailed concrete-filled 40-tonne steel closing doors with a 1–2mm verticality tolerance. Cell A required internal dimensions 12.35m long and 5m wide; Cell B was to be 9m long and 5m wide. Both cells would have an internal height of 7.7m; all walls were to be 1m thick and the roof 650mm thick.

For the concrete to create an effective barrier for the radioactive particles, the crack widths had to be controlled and limited to 0.1mm. This, of course, meant that the day joints were to be kept to a minimum. Working together, Calcinotto & Associates and Woodmace produced a scheme whereby the structure could be poured in a single pour of approximately 600m^3.

When pouring large quantities of concrete for walls 1m thick, there is an issue with the amount of initial heat gain. This was controlled by using a high content of GGBS of approximately 70% and a limestone aggregate with low shrinkage characteristics. The mix design, using the high quantity of GGBS, would extend the point of maximum temperature from 48 to 72 hours.

However, extending the curing time increased the initial setting period by 25%, thereby imposing high loads on the formwork for longer periods of time, making the design and the construction of the formwork more critical.

Constraints imposed by the consultant radiation company prevented the use of traditional through ties due to the obvious breaches in the wall integrity; therefore, five part radiation-proof SK bolts were used to meet the requirements.

As well as controlling the concrete temperatures with a designed mix, specialist formwork was required as a secondary measure. This was achieved by insulating the faces of all the formwork with a 25mm-thick high compressive strength insulating board between the formwork pan and the ply. This meant that the temperature differential between the core and the face could be limited to a maximum of 20°C.

An essential requirement from the structural engineer was to monitor the temperature of the concrete during the concreting process. Even though the mix was designed to reduce the core temperature and the formwork designed to insulate the temperature difference between the face and the core, the only way to be sure that the temperature requirements were achieved was to place 130 individual thermocouples around the structure in areas where the engineer was concerned about the effects of heat gain. Each point had two thermocouples, one in the core and the other 35mm from the face of the ply, so that the difference in temperature between the core and the face could be determined. To achieve this, five specially designed and constructed 30-channel data loggers and software, sent from America, were used to log each thermocouple every 15 minutes; this produced data into a temperature profile graph that was sent to the engineer every day for monitoring.

Due to the problems with such a tight specification in respect of controlling the differential temperatures, the decision was made to provide an enclosure scaffold around the entire cell, covered with shrink-wrap plastic. A heating specialist was employed to install an automated heating system to ensure that the temperature within the enclosure and internally within the cell would not drop below 20°C at any time. In line with the continual monitoring of the temperatures, the temperature of the cell was also regulated during the day with real-time data from the data logger system and if necessary the enclosure was opened up to reduce the internal heat.

Above: Structure completely stripped, door steelwork in place ready for hanging the 40-tonne doors.

Programme

The final issue to overcome was the construction programme. The design of the steel frame incorporated three gantry cranage systems as well as a four-storey office block. The close proximity of neighbouring boundaries required the steel frame to be erected during the erection of the formwork. This resulted in the steel frame being nearly complete before the cell was poured and, of course, the cell had to be struck and dismantled

Far left: All formwork in place prior to the external sheeted enclosure placement.

Left: Internal view of Cell A, showing the cast-in crane beams within the top of the cell.

Above: External sheeting in place prior to pouring and the final sheet installation.

> With the designed forces on the formwork calculated at 74kN/m², and with a concrete temperature of 15°C, the rate of rise during the pour was to be limited to 1m per hour.

after the steel structure had been completed. This required the formwork to be designed in such a way that it could be erected with a 40-tonne crawler crane and dismantled with 3-tonne mini-crawler crane. This required a limit on the panel sizes and co-ordination during the formwork design process to run with the construction programme. The issue with the size of the panels had further implications on the design of the panels: numerous reinforcing wailers were required, which in turn meant more bolts were also required. Careful consideration was given to the issues posed during the construction programme, as they had cost implications to the budget for the whole project.

With the designed forces on the formwork calculated at 74kN/m^2, and with an initial concrete temperature of 15°C, the rate of rise during the pour was to be limited to 1m per hour. However, the pour commenced at 6.30am in order to achieve the full 600m^3 in a single pour. The temperature at that time was as low as 11°C. With the wet concrete arriving approximately 1–2°C above ambient temperature, the rate of the pour had to be slowed down to avoid surcharging the loads on the bolts and formwork.

The pour was achieved using three concrete pumps – two to service the pour, with a third on standby in case of a breakdown. Hanson provided the concrete, running from two concrete plants, with a third plant on standby in case of a breakdown or a traffic issue that could affect the supply. Each concrete pump was serviced by separate gangs, filling the walls in a circular motion and using extra-long, high-frequency pokers. Within the cell, external formwork vibrators were used and moved up to match the rate of pour.

Once the engineer was in agreement in respect of the supplied concrete temperature profiles, the decision was made to strip the formwork from the cell. The maximum core temperature reached 51°C at 72 hours as calculated and the maximum temperature between the core and the face was 8°C, well within the 20°C limit. Inspection of the concrete faces confirmed there was no cracking that would void the design warranty from the engineer.

This was a very challenging project with an excellent finished result. Collaborating with the engineer several months prior to commencement enabled the design and sequence of construction to be fine-tuned; this produced an outstanding end product and a very happy client. ●

Above: Wall reinforcement being fixed in position.

The Radiographic Cell, Poole

Owner	Heatric
Structural engineer	Calcinotto & Associates
Formwork and concrete contractor	Woodmace
Concrete supplier	Hanson Concrete
Formwork supplier	Harsco Infrastructure

Judges' Comments

The structure has an impressive visual appearance, especially considering that this wasn't a particular requirement. The exterior was originally going to be painted but the finish was so good that it was left as-struck.

It does the job that it was designed to do and was reportedly cheaper to build than one using dense aggregate; it also doubles as a blastproof test chamber for water and gas pressure testing.

The tight specification in terms of temperature differential meant that 130 thermocouples were used to monitor temperature and several methods were combined (insulation, heated enclosure, leaving formwork on for six weeks) to ensure that the temperature differential was minimised. One continuous pour (including roof) avoided the use of any joints (apart from a quick-strip joggled joint for the labyrinth access 'tunnel').

A high standard of workmanship is evident in the finish achieved. Despite the high GGBS content there were very few 'sand runs' and none of any significance. Formwork tolerance around the 40 tonne doors was very tight as the 'seal' closure is part of the X-ray containment.

The two radiographic cells were constructed as the main fabrication building was built around them. This meant that the formwork needed to be dismantled using a smaller crane than was used to build it, requiring a considerable amount of forward planning.

This is a very impressive, innovative and logistical use of concrete to deal with several construction challenges.