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Achieving complex concrete features, finishes and shapes using five-axis technology

For designers considering the feasibility of including a complex, exposed concrete surface within their design proposal, the list of considerations can appear to be extensive. Factors influencing the finished concrete surface are numerous and while the requirements may seem onerous at times, exposed concrete with a complex geometry can prove breath-taking in appearance, when undertaken successfully. ***Simon Poole*** *of* ***Cordek*** *reports.*

For more straightforward concrete elements, considering the formwork requirements at the design stage may not seem necessary. Proprietary systems that are readily available on the market are designed in the main for forming flat, regular concrete surfaces where structural capability and performance is of the uppermost importance and surface finish requirements are required to be either 'basic' or 'ordinary', due to the intention to cover them with external finishes.

In addition to design considerations, another more simplistic factor often forgotten is that formwork for bespoke requirements, by the nature of its description, is not available 'off the shelf' and therefore early involvement between the design team and the formwork provider is encouraged. At this stage, factors such as the type of finish required, geometry and required tolerances can be considered. Furthermore, the added involvement of a contractor at this stage will allow consideration of positioning, striking and reuse of the formwork to be taken into account within its design.

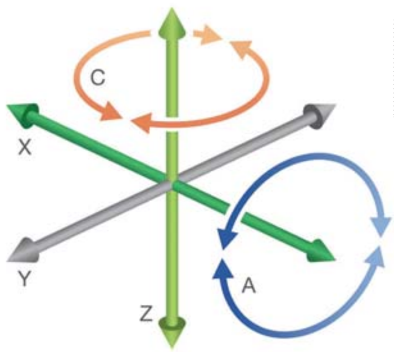
Assuming the principles of early involvement described above can be adopted,

Above: Royal College of Pathologists, London. Trough moulds used to create ribbed concrete floors.

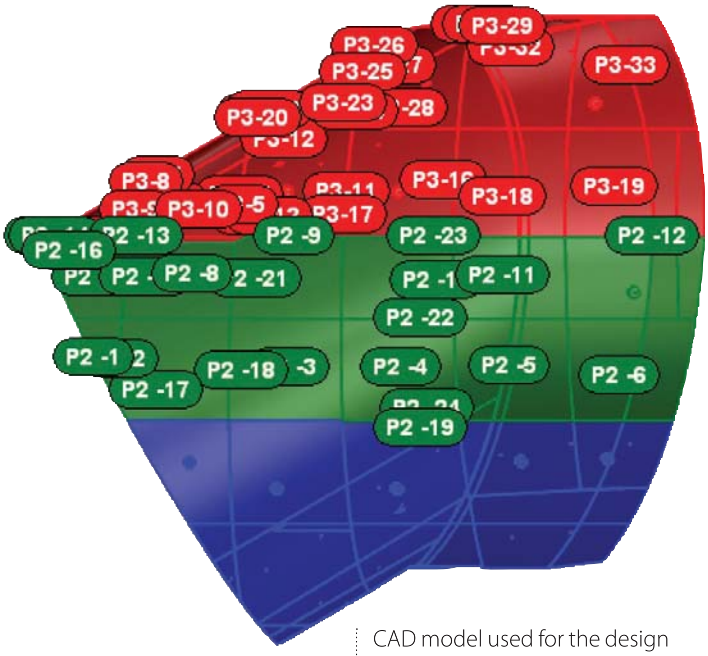
A five-axis router used in the manufacture of an EPS 'dome' former.

this will undoubtedly improve the chances of the designers' vision being realised. However, until relatively recently, the limitations of formwork systems have been in both the use of traditional materials only – eg, timber and steel – and the manufacturing technologies available within the industry.

The use of five-axis technology, where the cutting tool can move in a far wider range of axes than its more limited three-axis counterpart, has been adopted in industries such as aeronautics, automotive and marine design for some time. However, with regards to its use in construction and formwork manufacture, it can be considered a relatively innovative progression when coupled with computer-aided design (CAD) to computer-aided manufacture (CAM) conversion and digital scanning techniques now available.



The five axes in which the routing head of the machine is operational.



CAD model used for the design and manufacture of the Farringdon Station escalator shaft two, London 'knuckle' former.

The term five-axis refers to the number of directions in which the robotic arm and cutting tool can move, which includes the X, Y and Z linear axes, in addition to rotating on the A and C axes to allow approach to the workpiece from almost any direction. This increased range of capabilities means that complex patterns and moulds for use with precast manufacture and bespoke formwork solutions for cast-in-situ applications, can be created using a range of materials.

This type of manufacturing technology particularly lends itself to formwork applications that involve complex, curving (often in multiple directions) surfaces in the concrete, to be formed to a high degree of geometric tolerance. Smaller-scale applications where precasting is the preferred option, can adopt the use of machined patterns from which impressions or moulds can be taken. This approach is often taken when manufacturing glass-reinforced plastic (GRP) moulds from patterns produced in either modelling board or paste.

Hydrostatic forces

For cast-in-situ concrete applications, due to the scale, often the formwork solution required is positioned inside a supporting falsework to cope with the hydrostatic forces relating to the concrete pour. To this effect, the bespoke element of the formwork system becomes a 'liner' to which the concrete is cast against, allowing complicated and intricate features to be created both consistently and economically. Often, the size of cast-in-situ concrete applications means that the formwork solution is supplied in a 'segmental' format, requiring mating surfaces between units to meet perfectly, with minimal site adjustment required. The use of five-axis technology means not only far higher degrees of accuracy when compared with site-formed formwork solutions but also ensures conformity between units that either adjoin or are of the same type.

Castable rubber formwork liners are flexible in both their physical characteristics and the range of applications to which they can be applied. Positioned within the supporting formwork/falsework system, they are suited to the formation of patterned concrete or subtle architectural features within the exposed concrete surface. However, their manufacture is often reliant on the five-axis routed mould into which the liquid rubber is poured and then demoulded from, when suitably cured. The high degree of accuracy and ability to manoeuvre the cutting tool around the mould substrate, makes the complex achievable.

Regardless of the formwork solution deemed most appropriate, the use of CAM methods can be complemented at the final stages of the quality assurance and control processes through the adoption of laser-scanning technology to digitally scan the finished surfaces that the concrete will be cast against. Complex, curving surfaces cannot be measured accurately by conventional means and therefore the use of laser-scanning technology to identify any non-conformance completes the progression to a fully digitised process.

The adoption of technologies already established in other sectors, will help the construction industry to keep pushing the boundaries of what is possible to be formed using concrete. The use of five-axis technology, supported by 3D modelling at the design stage and digital scanning to ensure accuracy before use, is the 'direction of travel' for the bespoke complex formwork industry. Cost-effectiveness coupled with the almost limitless range of applications for which formwork solutions can be found, means that realisation is confined only by the imagination. ■

Above left: Folkestone Urban Sports Park, Kent. Formers used for construction of suspended skating bowls supported by proprietary formwork/falsework.

Top: Digital scanning of a precast concrete cladding mould to ensure compliance with specified tolerance.

Above: Ely Southern Bridge, Cambridgeshire. Bespoke formwork solution used to create complex geometrical features within supporting piers.