TALKING TO MACHINES

THE CONSTRUCTION INDUSTRY CAN INCREASE PRODUCTIVITY AND QUALITY WHILE REDUCING ENERGY CONSUMPTION, LOWERING COSTS AND SAVING TIME THROUGH CREATING STRONG LINKS BETWEEN DESIGNING AND MAKING THROUGH 3D VISUALISATION, SAYS ANDREW WATTS

Throughout history, to understand and visualise the complexities of buildings, models have always been made. For centuries, these were physical scale models that allowed a close examination of the proposed structure. More recently, digital models have performed the same function. These not only allows stakeholders to comprehend the project but also provide the ability to ensure that crucial decisions are based on the fullest and most detailed information available. Today, visualisation of projects is performed using 3D CAD which can be supplemented by photographs of surrounding geography and linked to geological, geospatial and physical entity survey data including LiDAR output.

By committing designs and associated information and data to digitalisation using CAD and CAE (computer aided engineering) it is possible to achieve total quality assurance for each component of the building, and of the entire finished part. This occurs because by designing and then manufacturing components digitally, any technical, structural and aesthetic issues can be resolved in advance of physical work commencing. Finished products can be scanned and measured then directly compared with their digital representations for accuracy. This meshing of digital and physical worlds means that building components conform to their specifications and are therefore guaranteed for fit and performance.

This use of 3D technology is not news to engineers and architects, who are often highly digitalised. But the digital chain is often broken between building designers and contractors. However, when links are strengthened through the whole supply chain, the results are spectacular.

Leading the world

The design of the envelope of the KAFD Metro Station in Riyadh, Saudi Arabia, was driven by the need to provide a weather-tight and thermally insulated envelope around a supporting structure. The geometry of the envelope is not driven by a structural primitive that seeks to provide structural efficiency, but by the requirements to enclose the interior space with the minimum amount of internally air-conditioned volume. Consequently, the zones for the depth of the facade and its supporting structure are required to be minimised to contribute to this concept.

To understand and analyse this complex design the building comprising thousands of individual components had to be modelled using a CAD system that generated accurate and practical geometry for fabrication. Once the 3D digitisation was completed each stakeholder had access to the design and could thereby comprehend the work involved in bringing it to a successful conclusion. Throughout the build the digital and physical entities were compared and any required adjustments to production or construction made. Finished components were scanned and their data fed back into the model for analysis.

The KAFD Metro Hub as it will look when finished.

DEPLOYING THESE TECHNIQUES MEANS THAT AMAZING BUILDINGS CAN BE DELIVERED AT ORDINARY PRICES

In order to fix each cassette module to the supporting steel structure, the principles of 'spider' fixing technology have been utilised to ensure high levels of adjustment and flexibility, but avoiding the use of a casting, with its higher costs, by using two independent elements fixed to a single threaded bar. This technology is derived directly from fixings for glazing panels which are supported on cables or lightweight steel structures. These 'spider' fixings are used to accommodate high levels of movement of the supporting structures without generating stress concentrations at the points of support. The movement and adjustability are achieved by means of a ball joint located at the end of each spider leg which allows a limited degree of rotation. A combination of CAD and finite element analysis was deployed to ensure that the fixings were optimised to their function and would provide structural integrity for the life of the building. Since the future may see robots servicing and maintaining the building this was also considered in the design with points of attachment provided. This mean that expensive and cumbersome cranes will not have to be used to lift and replace panels. Scanner equipped drones will also increasingly be deployed to inspect the building and the data they collect be used to assess maintenance requirement through comparison with the original 3D CAD model

The geometry was rationalised through a set of early stage iterative studies that introduced a slight double curvature in the perforated parts of the envelope which were subjected to larger deflections. This allowed a significant reduction in the size of the steel of the primary shell structure for these areas, without visibly changing the architectural intent. These studies were made possible as a result of applying the results of a preliminary finite element analysis of the building to the structural model of typical areas of facade.

Flexible decision making

By simulating through digital design and representation and considering and studying everything in advance of physical work, it is possible to understand the true implications of project choices and decisions. Digitising projects enables flexibility because general properties can be analysed in relation to fine details. This means that decisions over materials can be made with a full understanding of their cost, aesthetics and construction technique implications.

Working this way means material parameters can be better understood and designers can go beyond simply claiming that a certain component or finish is better. They can prove it in terms of material or fabrication cost in addition to visual considerations.

Using digital models to explain building techniques to contractors and work with them to develop and optimise strategies can be done at an early stage to improve outcomes. By combining all the project knowledge including scans, photographs, wind and stress analysis results and incorporating them into a 3D digital CAD model all stakeholders have access to the information they need and can better understand the implications of their work in relation to others. It also provides planners and managers with the ability to check plans against outcomes and take appropriate action in response.

Adding these types of services to the production of buildings is new for many contractors. But those that that we work with discover that the application of fully visualised engineering design becomes their 'service element' allowing them to present fully performance-validated solutions to their customers. This in turn lets them win more contracts in the confidence that they can be fulfilled on time and to budget.

Code

Computer code is the shorthand that delivers the robust instructions that solve complex engineering problems. It also provides the living user manual to operate the building for decades to come. Every design, test and action related to a building's genesis, construction and maintenance is captured. This record becomes available to anyone who needs to engage with the project.

The advanced structure that forms the facade of Botanica, an innovatively conceptualised residential block in northern Queensland, Australia, could have been made from either steel of concrete. By simulating and visualising the design, fabrication and construction parameters of both options the cost was calculated with a high degree of precision and concrete was selected. In the past, this decision would have put more emphasis on material cost but because every aspect was fully and accurately modelled, visualised and considered in advance the true cost was revealed. This digital strategy assesses and addresses risks in new ways that seek to define all parameters so that risk can more easily be understood, calculated and managed and costs and schedules guaranteed.

Deploying these techniques means that amazing buildings can be delivered at ordinary prices. Designs can evolve smoothly to suit all parties and various design options considered and proven.

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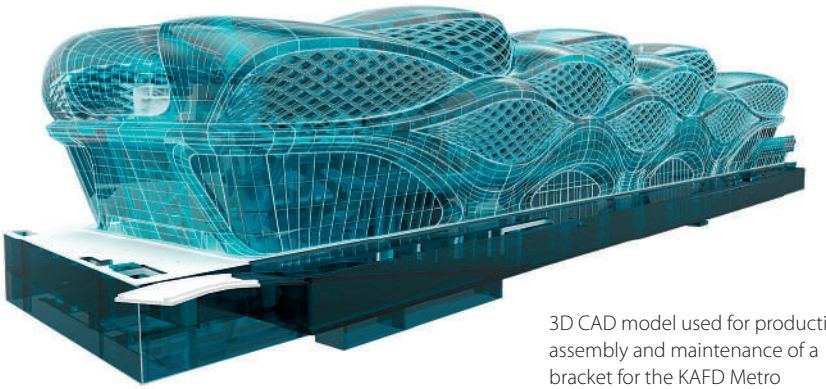

3D CAD model used for production, assembly and maintenance of a bracket for the KAFD Metro