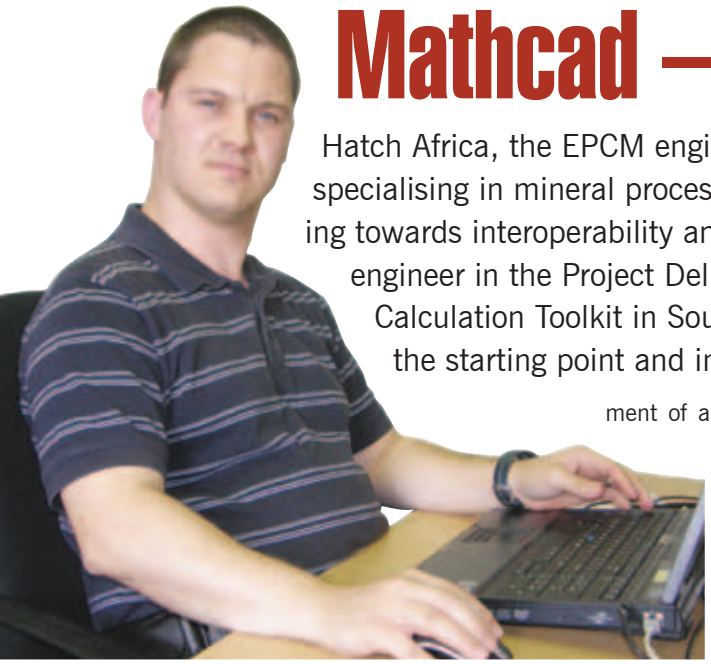
Mathcad – a new springboard for

Hatch Africa, the EPCM engineering, project and construction management consultancy specialising in mineral processing, mining, energy and infrastructure, is currently striving towards interoperability and integration for its software tools. Johan Palm, a senior engineer in the Project Delivery Group, is driving the implementation of the Hatch Calculation Toolkit in South African offices, a global system that uses Mathcad as the starting point and integrator of engineering design.



Johan Palm, a senior engineer in the Project Delivery Group.

Mathcad started to be used in Hatch's Mississauga office in Toronto more than 10 years ago. "About four years ago, our global structural director made the decision to adopt Mathcad globally in preference to calculation spreadsheets," explains Palm. The Brisbane office developed an engineering calculation toolkit (HatchTools) that uses Mathcad at its core, allows for calculation format standardisation and the management of a global calculation library. The HatchTools system is part of Hatch's global collaborative design strategy.

"Engineering calculations done in Mathcad can naturally be validated because its visual format mimics normal paper-based calculations. This allows any engineer, working anywhere in the world to customise and improve formulae and the design of standard calculations in the library to suit a specific project design requirement.

Improved calculations can then be added to the global library and numerous contributions then allow the calculations to mature over time, the Wiki principle," says Palm. You can't do this when using spreadsheets. The formulas are hidden and difficult to track, so in general, only the creator can work with and further develop spreadsheet-based calculations.

"This is especially true when you consider the complexity of the calculations we need to do," he adds.

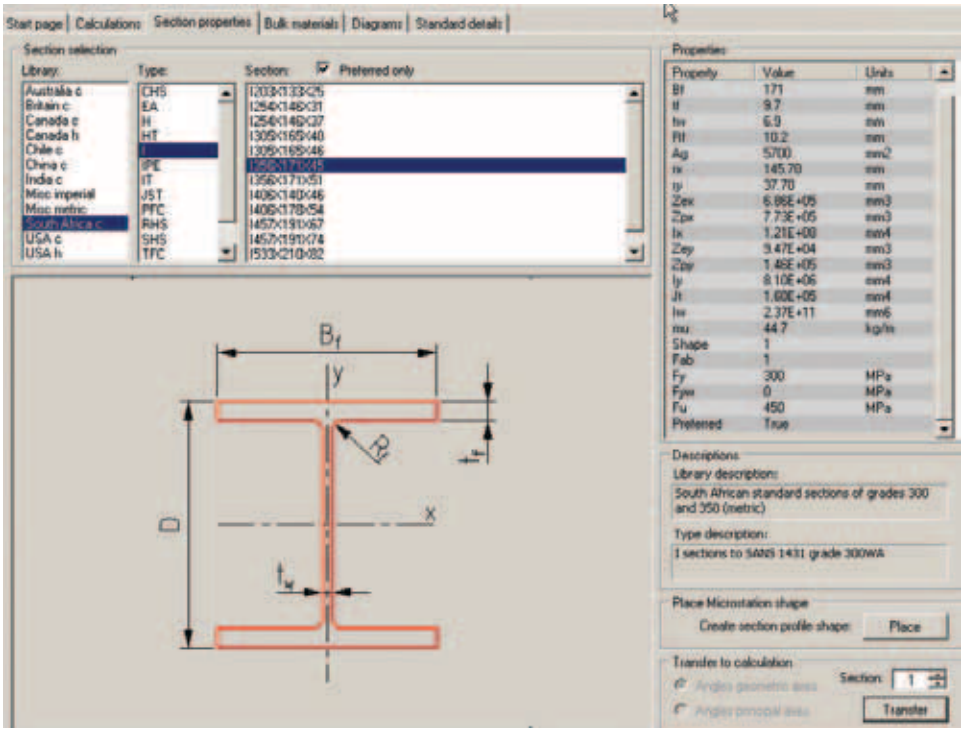
Mathcad has an automatic unit verification feature which will immediately show if a formula is wrong by checking the units. "So if you need to do a stress calculation, and you know that the units must come out in MPa, the program will tell you that something is wrong if they don't," Palm explains.

Mathcad was also chosen to replace calculation spreadsheets because of its compatibility with OpenText LiveLink (iPas DM), Hatch's enterprise document management system. Any calculation, no matter how long, can be saved in Adobe PDF format and passed automatically into the document management system. "In 10 years from now, if anyone wishes to validate a design calculation, they don't need to worry about which software or software version was used in the first place. All they need is a PDF reader," he says.

Palm opens up the Hatch Calculation Toolkit on his laptop. "All of our standard Mathcad calculations are in our globally accessible library. Any engineer can access a calculation from the library. He can then use and improve the calculation on projects and post it back into the library as an improved calculation," he explains. "It is a truly global system. When you open up the Hatch Calculation Toolkit, you immediately get a list of daily updates, and everyone, anywhere in the world, uses the same updated system."

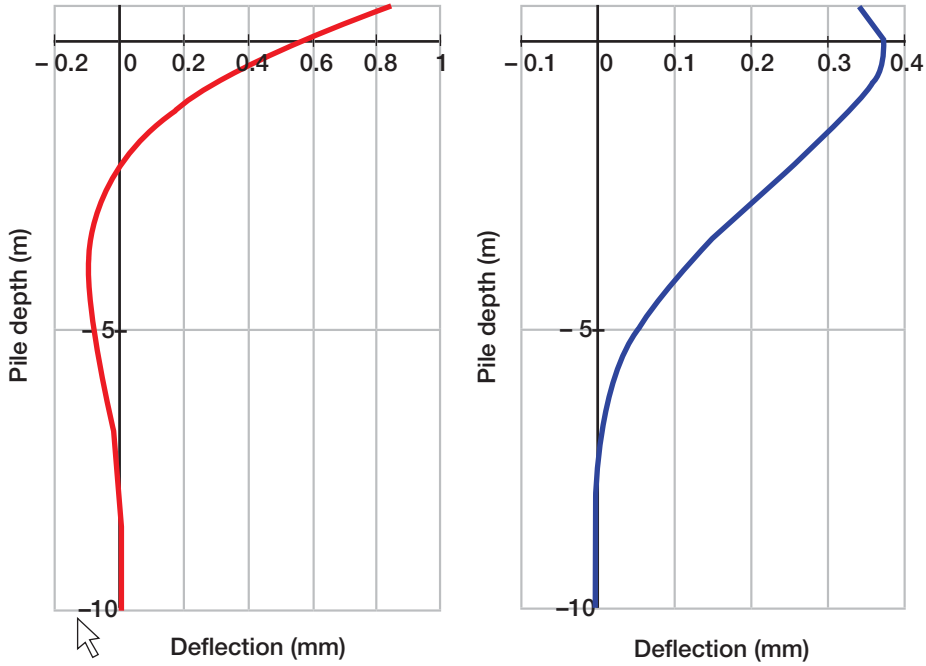
The philosophy is that the Tools library is improved through real projects. "We don't have a separate team of people developing standard calculations that might never be used. Instead, because it is a single source library, clients get the full benefit of all previous projects and any relevant development within the Hatch group anywhere in the world," Palm informs *MechTech*.

He gives us a demonstration by selecting



Selecting a structural steel member from Hatch's global section properties database. All of the section properties are accurately transferred into the Mathcad, hence avoiding transcription errors that could occur if using catalogues.

integrated engineering design



A deflection profile of a pile supported by soil based on a finite-element stiffness analysis completed in Staadpro. "All pre- and post-processing is done in Mathcad, but the FEA is done in Staadpro," explains Palm.

a beam internal force calculation for crane loads from the library. The Mathcad window is populated: "This will calculate the maximum bending moment and shear forces for a given beam supporting a moving crane," he explains, "and it is now live, that is, as soon as the formula is pasted into Mathcad, you can edit and evaluate results interactively. Any change immediately produces the corresponding result."

This is a structural steel member design calculation, according to the South African steel code, which was adopted from the Canadian code. Palm selects a double-symmetrical I-beam section. "There are a huge number of these steel sections that could be used," he says. He goes to the global section properties database in Hatch Tools, selects South Africa, preferred I-section, preferred sections only. He selects a section and clicks transfer. All of the section properties for this particular steel beam, with the correct units, are accurately transferred into the Mathcad window on the left.

"All the section properties are now reflected through the calculation below. All the input variables are highlighted in yellow, good practise to help people follow the calculation. For every step in the calculation, it shows you the formula and the calculated result with the associated calculated units. That is why it is so much better than spreadsheets, which shows neither the formula nor the units. Mathcad, although not new in itself, is the modern way of doing engineering calculations," says Palm.

Interoperability is important to Hatch. It allows for efficiency by not duplicating engineering information in different systems. "Hatch has extended Mathcad and created interoperability objects, which links Mathcad to: StaadPro, a Bentley finite element analysis program for beam and shell elements; MicroStation, a 3D CAD modelling program; Strand 7, another FEA package; and Excel, for its mass, batch of matrix calculation ability," he says.

He shows us a concrete pile design example. "When you design a concrete pile, you design for the soil capacity and the physical member capacity of the pile itself, but you cannot do it with Mathcad only. You need to use an FEA package as well," he explains. "This calculation is also going to be done four times because different wind load combinations give different reactions onto the building, which need to be taken up by the foundations, ie, through the pile and into the soil. HatchTools iterates in Mathcad through all the load cases to determine the critical failure mechanism for the pile design."

Hatch has developed a scripting language in Mathcad for Staadpro, the FEA program. "We embed a Staadpro object into Mathcad to make its FEA capability accessible from within Mathcad. In this analysis, we simulate the soil support by assuming that circumferential springs support the pile at several intervals along its length. StaadPro then does a stiffness analysis on the pile, taking inputs about the soil and the pile from Mathcad and returning analysis results back. All pre- and post-processing is done in Mathcad, but the FEA is done in StaadPro," explains Palm.

He shows us the FEA analysis running in the background and then moves down in the Mathcad calculation to a chart of the deflection profile of the pile. "Also coming out are the different critical failure mechanisms for each of the different load cases and the critical load case and failure mechanism are highlighted," he adds.

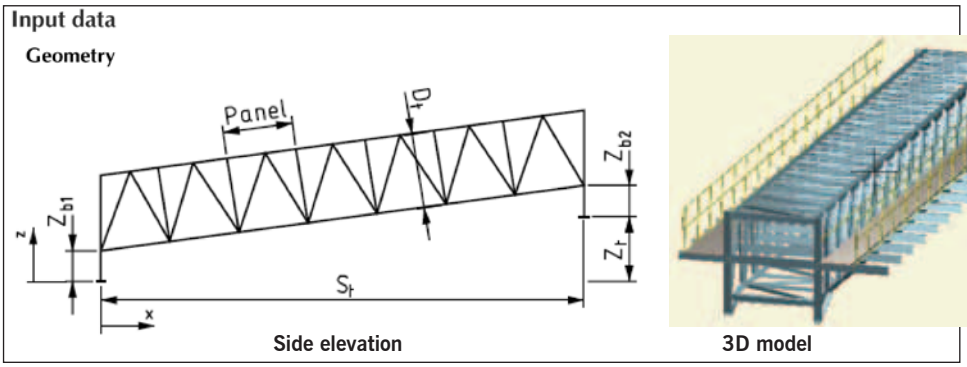
The scripted link to Bentley's MicroStation program allows intelligent 3D CAD models to be built directly from calculation results produced in Mathcad. "We are taking the parametric route through Mathcad and this allows us to use the engineering design as the starting point, and to fully integrate the engineering design with the 3D model. By doing this we can create detailed 3D designs of components that are dynamically linked to the engineering calculation in Mathcad."

He demonstrates how this works by opening up a Mathcad material conveyor design calculation from the Hatch Calculation Toolkit Library. Palm selects an I-section for use in the design and brings the parameters across.

He selects a span (20 m), a number of panels (9). "I call this a Mathcad program because it is much more than just a calculation," he says, showing the truss shape of a conveyor structure with side walkways. He then takes us to a library of conveyor section parameters – top chord, bottom chord, vertical angles, vertical members, etc – and transfers section number five.

"The StaadPro FEA analysis is initiated by Mathcad for each individual conveyor support segment, and then Mathcad passes the results into Bentley Structural, a component of MicroStation, which creates the intelligent 3D model." He clicks into MicroStation and we see a 3D model of a conveyor structure.

"Very few companies can dynamically integrate fully documented calculations with



The conveyor design program, which embeds Staadpro and Bentley's 3D modelling program, MicroStation into Mathcad, enables 3D models of components to be built directly from engineering calculation results.

engineering analysis and design – and this intelligent 3D CAD model is ready for drawing production!" he exclaims. To reinforce the power of the system, he changes the Mathcad calculation variable for the number of panels from 9 to 16, and presses F9 to recalculate.

The Mathcad calculation updates the analysis, the design and the 3D model changes to one with 16 panels, "and by the end of the year, we will have also incorporated Bentley ProSteel, which will automatically create the manufacturing drawings and numerical control files for machine tools that can automate fabrication," he adds.

But this is not all. "Some people say that Mathcad is not good for batch calculations – repetitive calculation with 200 or more options for input variables – but our international colleagues in Australia have developed a Mathcad batch calculator to incorporate this feature."

Palm explains how this works: "We set up a single Mathcad calculation with all of the formulas required for the calculations. We then set up a table of all the input and output variables in Excel. The batch calculator macro in Excel feeds all the associated tabulated input variables into Mathcad, which does the calculation of the Excel table row by row.

"The result of each Excel table row is then passed back into the Excel spreadsheet and entered as table output variables. So all of the actual calculations are done in Mathcad and Excel is only being used to iterate the calculation through the different options in a table format," he says, "and for auditability, we can also automatically create a PDF file for each individual row of the calculation," he adds.

"Twenty years from now, there may be a better tool for engineering calculations than Mathcad, but the PDF output from Mathcad documents our calculations in a natural engineering calculation format, which can be accessed forever, for any engineer to print out and understand," Palm concludes. ❑