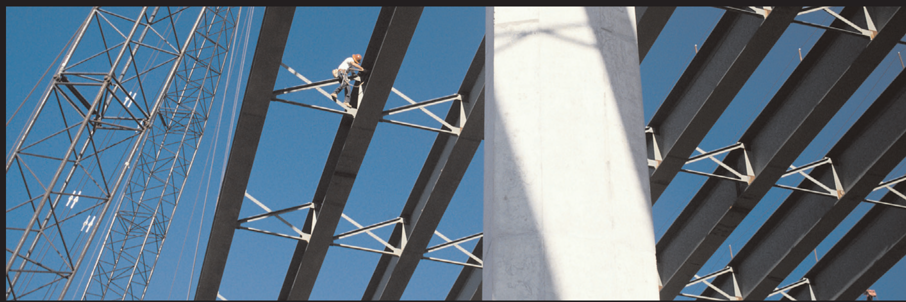
Putting your PC to work

Why thousands of civil, structural and mechanical engineers have invested in Mathcad



Ever wondered why some engineers regard their PC almost as another member of the design team? Take a look and you'll probably find their main application is Mathcad.

For too long, too many engineers have been asked to expend too much of their creativity adapting to tools developed for other disciplines. Spreadsheets developed for accountants. "Word processors" developed for administrators.

But there is a tool - indeed, a complete PC environment - developed by engineers with the needs of engineers at its heart. That tool is Mathcad, and it's quietly become one of the most widely-used technical applications in the world.

Mathcad is a technical document creation system, an engineering calculation environment and a mathematical reference library which, with the addition of libraries and on-line resources, can be made even more relevant to individual specialisations such as mechanical and structural engineering. It's all these things, and more. Mathcad solves mathematical problems, generates graphs and visualisations, and does everything you'd ever dreamed a PC application for engineers would do. If you know how much your time is worth, you'll know it's time to take a look at putting Mathcad at the heart of your work.

This pack uses a few examples to give you a brief introduction to how Mathcad can start to really make your PC work for you. Read how the Office of Bridge Design at South Dakota's Department of Transportation turned to MathSoft's Mathcad program for help with repetitive calculations not handled by the bridge design software. Take a look at a sample from one of the Mathcad "Electronic Books" from the electronics engineering and electrical engineering sectors. More than a reference, Electronic Books actually perform the operations they document: see how "Heat Conduction in Buildings: the Transient One-Dimensional Finite Difference Wall Model" doesn't just describe the process: it actually does the complete calculations.

With continuous input from over 1.5 million users worldwide, Mathcad has been developed into one of the most wide-ranging applications on the PC today. When you've taken a look at this pack, move across to **www.mathsoft.com** for more information or call one of our product experts to discuss what it can do for you.

Let's reclaim the PC for engineers.

Mathcad®

MathSoft

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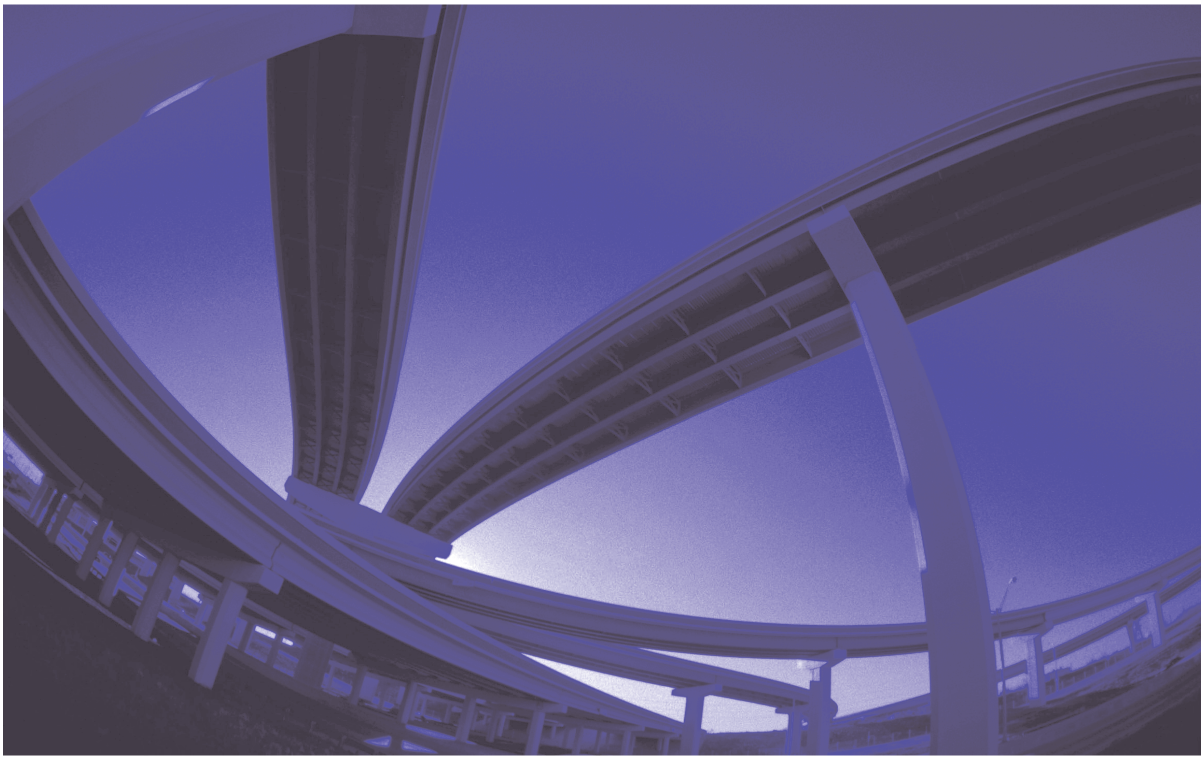
Leaving a "Road Map" for Future Engineers

For calculation and documentation, the Office of Bridge Design turns to Mathcad



The Office of Bridge Design at South Dakota's Department of Transportation provides design and construction engineering services for more than 1,780 bridges throughout the state. Safety and cost effectiveness are the top priorities of this department, particularly because bridges are designed to last at least 75 years.

Bridge replacement or rehabilitation projects become part of the Department's 5-year construction program. Once a bridge repair or construction project is approved, engineers are charged with developing plans to meet specifications based on national bridge design standards and the Department's standard practices. Incorrect calculations could mean a steel beam not able to withstand the necessary load, or a bridge that can't stand up to the wear and tear of the elements. The South Dakota DOT turned to MathSoft's Mathcad program for help with repetitive calculations not handled by the bridge design software.

"Mathcad replaces the Excel spreadsheet that we might have used in the past, to provide a more elegant and better documented design tool," says John Cole, chief bridge engineer.

Before adopting Mathcad, engineers used a combination of traditional spreadsheets and hand-written calculations for portions of the structure design not completed by the design software.

"We wanted to streamline the long, tedious calculations necessary for bridge design and get people off the spreadsheets they were using," said Levi Hillmer, transportation project engineer, Office of Bridges and main user of Mathcad. "With Mathcad, you can see the formulas. In addition, it's easy to personalize the software to meet standard specifications and regulations."

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The accuracy of the hundreds of calculations the department completes each week is closely reviewed in a process that involves the designer and an independent check designer. Using two independent designers, who often use different software programs, greatly minimizes the possibility of a design error getting into the plans.

By including formulas and annotations, Hillmer says that he is leaving a road map for future engineers that have to revisit the projects he has worked on.

"I can put in the standard specification, and where it’s located. If somebody has a question about it, they can go back and look where I got it from and see how the formulas were calculated. In ten or fifteen years, when somebody comes back and sees a design, they can immediately go back to the notations."

This capability is extremely important when reviewing the original calculations for rehabilitation work, or if there is a structural problem. Engineers can go back to Mathcad, look at the original calculations and see what design assumptions were made or if the standard specifications have changed since construction.

While the main bridge design/analysis software will continue to be dedicated software packages such as OPIS, over time, Mathcad will be used to replace an increasing number of repetitive hand calculations, many of which are still done in pencil.

"One other benefit of Mathcad is for long term records storage," says Cole. "Printed Mathcad calculations are recorded on microfilm much better than pencil."

"Mathcad allows engineers to accomplish five days worth of calculations in one day while leaving behind a historical footprint that can be used for bridge repair or maintenance for years to come," said Hillmer.

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Real-math notation keeps everyone on the same page

Mathcad's Format Ideal for Florida DOT

When you are Florida Department of Transportation (FDOT) Structural Engineer Andre Pavlov and are involved with over 100 consulting engineers working on Florida's 6,000 bridges and 12,000 miles of state highway, it is essential to have a standard for technical calculation and design communication. Calculations must be precise, and information must be communicated in both a timely and easy-to-understand manner, especially in a hurricane-ridden state.

With all the moving parts and many projects within the FDOT, everyone needs a way to keep designs and calculations all on the same page. For those reasons, the FDOT uses Mathcad to ensure smooth communications and design efficiency. Mathcad, via its white-board interface, offers a straightforward but powerful equation-based solution that frees engineers from the traditional pen and paper and makes it much easier to share and reuse work. Employing real-math notation, Mathcad allows engineers to receive and view designs that are clearly documented and simple to understand, review and approve.

"We need our work to be visible," explains Pavlov. "We can write the programs in Fortran, but then you would not be able to see the logic of the engineer's design. Mathcad is the only software I know where I can print out the file, hand it to an engineer, and by just looking at the paper, they can understand what's going on."

It is not uncommon for consultants to hand the FDOT 50 pages of calculations for the design of a pre-stressed concrete beam, concrete box culvert, or cantilever retaining wall. For most jobs, the engineer can use the FDOT programs that all run within Mathcad. Even with the analysis of a concrete column, the FDOT's program interface is written in Java but relies on Mathcad to calculate the numbers.

Using Mathcad templates, the FDOT can easily distribute information to manufacturers and contractors who bid for specific construction projects. Because Mathcad uses common math symbols and employs a live math interface with the incorporation of MathML, the contractors have instant access to data and can input variables appropriate to their particular project without recreating design models.

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"Mathcad is an integral product for my work at the FDOT," said Pavlov. "With Mathcad, it's easy to disseminate design calculations because the documents look like real math."

"There's very little I can't do in Mathcad," concluded Pavlov. "The main benefits come from the format, which resemble a typed set of calculations. These programs are easier to develop by engineers and easier for others to follow and review since the logic is expressed in a familiar manner. The format is what places Mathcad head and shoulders above other programs of a similar function."

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Heat Conduction in Buildings: Transient One-Dimensional Finite Difference Wall Model

Transient thermal analysis of walls or rooms may be performed with the following objectives:

1. Peak heating/cooling load calculations
2. Calculation of dynamic temperature variation within walls including solar effects, room temperature swings and condensation on wall interior surfaces.

In the transient finite difference method, we represent each wall layer by one or more sub-layers (regions). Each region is represented by a node with a thermal capacitance C connected to two thermal resistances, each equal to half the R-value of the layer, forming a T-section as shown in the figure below for the concrete layer.

For a multilayered wall, an energy balance is applied at each node at regular time intervals to obtain the temperature of the nodes as a function of time. These equations may be solved with the implicit method as a set of simultaneous equations or with the explicit method in which we march forward in time from a set of initial conditions.

The general form of the explicit finite difference formulation corresponding to node i and time interval p is

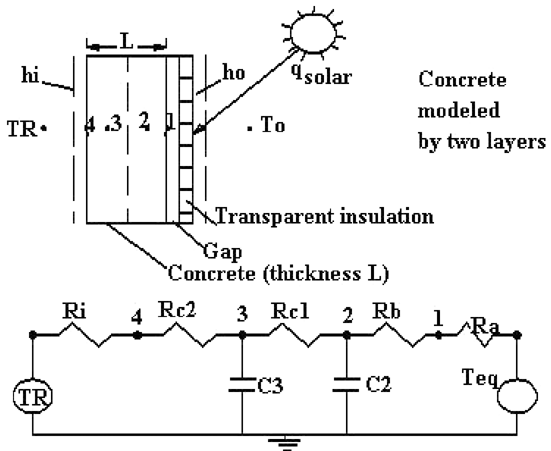
$$T(i,p+1) = \left(\frac{\Delta t}{C_i}\right)\cdot\left(q_i + \sum_j \frac{T(j,p)-T(i,p)}{R(i,j)}\right) + T(i,p)$$

Critical time step:

$$\Delta t_{critical} = \min\left(\frac{C_i}{\displaystyle\sum_j \frac{1}{R_{i,j}}}\right)$$ for all nodes i.

Example

A wall employs the new concept of transparent insulation. It consists of a transparent exterior layer, an air gap, and a concrete thermal storage layer.



$degC \equiv 1$ $\qquad A := 1\cdot m^2$ $\qquad L := 0.12\cdot m$

Concrete properties:

$c := 800\cdot\frac{joule}{kg\cdot degC}$ specific heat

$k := 1.7\cdot\frac{watt}{m\cdot degC}$ conductivity

$\rho := 2200\cdot\frac{kg}{m^3}$ density

$h_i := 10\cdot\frac{watt}{m^2\cdot degC}$

$h_o := 20\cdot\frac{watt}{m^2\cdot degC}$ film coefficients

$\tau\alpha := 0.7$ effective transmittance-absorptance

$R_{ins} := 0.3\cdot m^2\cdot\frac{degC}{watt}$ $\qquad R_{gap} := 0.3\cdot m^2\cdot\frac{degC}{watt}$

$$R_a := \frac{R_{ins} + R_{gap} + \frac{1}{h_o}}{A} \qquad R_a = 0.65\,\frac{degC}{watt}$$

$$R_c := \frac{L}{k\cdot A}$$

$$R_b := \frac{R_c}{4} \qquad R_b = 0.018\,\frac{degC}{watt}$$

$$R_{c1} := \frac{R_c}{2} \qquad R_{c1} = 0.035\,\frac{degC}{watt}$$

$$R_{c2} := \frac{R_c}{4}$$

$$R_i := \frac{1}{A\cdot h_i} \qquad R_i = 0.1\,\frac{degC}{watt}$$

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$$C2 := \rho \cdot c \cdot \frac{L}{2} \cdot A \qquad C2 = 1.056 \times 10^{5} \frac{joule}{degC}$$

$$C3 := C2$$ thermal capacitances

Stability Test

The time step Δt should be lower than the minimum of the two values in the vector TS.

$$TS := \left(\frac{C2}{\frac{1}{R_a + R_b} + \frac{1}{R_{c1}}} \quad \frac{C3}{\frac{1}{R_{c1}} + \frac{1}{R_{c2} + R_i}} \right)$$

$$\Delta t_{critical} := \min(TS) \qquad \Delta t_{critical} = 2.867 \times 10^{3} \sec$$

Choose Δt:

$$\Delta t := 1800 \cdot sec$$

$$Steps := 96$$ number of time steps

$$t := 0 \cdot sec, \Delta t .. Steps \cdot \Delta t \qquad i := 0 .. Steps$$

Assume

$$w := 2 \cdot \frac{\pi}{86400} \cdot \frac{rad}{sec}$$ frequency based on period of one day

$$To(t) := \left(5 \cdot \cos\left(w \cdot t + 3 \cdot \frac{\pi}{4}\right) - 5\right) \cdot degC$$ outside temperature

$$f(t) := 500 \cdot \cos[w \cdot (t - 43200 \cdot sec)] \cdot watt$$

$$q_{solar}(t) := if(f(t) > 0 \cdot watt, f(t), 0 \cdot watt)$$

incident solar radiation modeled as half-sinusoid

$$Teq(t) := To(t) + q_{solar}(t) \cdot \tau\alpha \cdot R_a$$

equivalent “sol-air” temperature

$$TR := 22 \cdot degC$$

room temperature

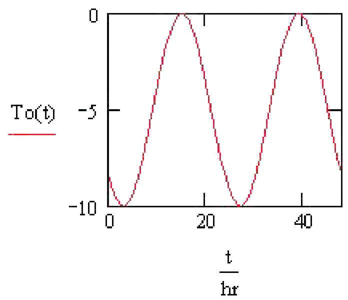
Initial estimates of temperatures:

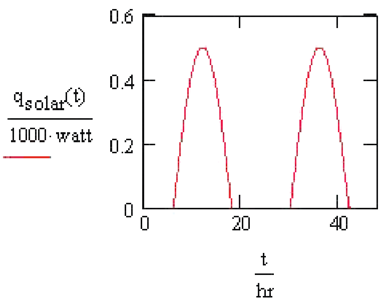
$$\begin{pmatrix} T2_0 \\ T3_1 \end{pmatrix} := \begin{pmatrix} 0 \\ 0 \end{pmatrix} \cdot degC$$

$$\begin{pmatrix} T2_{i+1} \\ T3_{i+1} \end{pmatrix} := \begin{bmatrix} \frac{\Delta t}{C2} \cdot \left(\frac{Teq(i \cdot \Delta t) - T2_i}{R_a + R_b} + \frac{T3_i - T2_i}{R_{c1}} \right) + T2_i \\ \frac{\Delta t}{C3} \cdot \left(\frac{T2_i - T3_i}{R_{c1}} + \frac{TR - T3_i}{R_i + R_{c2}} \right) + T3_i \end{bmatrix}$$

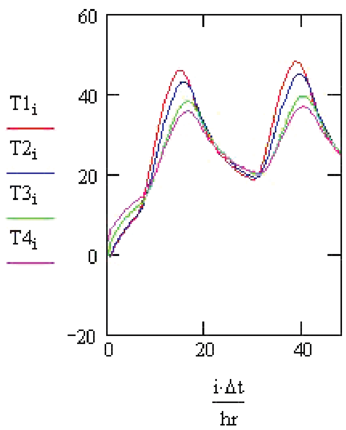
$$T4_i := TR + R_i \cdot \frac{T3_i - TR}{R_{c2} + R_i}$$

$$T1_i := T2_i + R_b \cdot \frac{Teq(i \cdot \Delta t) - T2_i}{R_b + R_a}$$





Variation of nodal temperatures for two days (T4 is room-side wall surface temperature, T1 is the concrete gap-facing temperature).



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Mathcad is the right solution for the right job at Dynamic Air

Len Williams, MD of Dynamic Air in the UK, is finding Mathcad a better answer to many in-house problems which he would once have had to write dedicated programs to solve. With Mathcad it is easy to re-use calculations in other projects or share the routine with colleagues which means there is no unnecessary reiteration of work already done.

Dynamic Air Inc. has, in just over 30 years since its formation, established itself as a worldwide force in bulk materials movement. From bases in Australia, Brazil, the US and the UK, it serves customers and licensees across five continents. Ten thousand of their industrial-scale systems from the corporation move substances ranging from ABS resin to zirconium silicate, in huge quantity, for industries as diverse as steel production, pharmaceuticals and waste water management. These systems are, as the corporate name implies, pneumatic; the aim is to maintain smooth fluid-like flow of finely divided product or raw material at high speed through the stages of a given mass process.

The systems are built to four basic models, from a portfolio listing some thirty or so fundamental types of component, but all share a common dependence on pipelines built from a limited range of modular sections. Finding and communicating the most efficient combination of these sections is one area in which Mathcad has contributed to savings of time and resources, without the need for programming from scratch.

Changes of direction in a pipe are constructed from two root bends (_/6 and _/12 radians respectively). Judicious multiple combination of these segments, in conjunction with suitable rotation about the local pipeline axis at the points of junction, can yield any three-dimensional change in direction. The tricky part is achieving the best solution; time is money, and solving such bends unaided is a time consuming business which Mathcad was well placed to streamline. A

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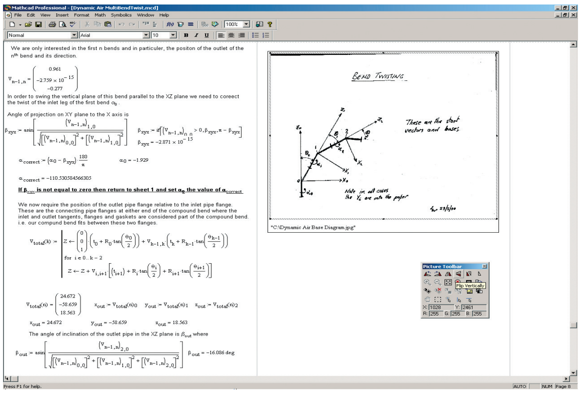

few minutes spent playing with models reveals, beneath apparent simplicity, a visualisation and manipulation problem on a par with Rubik's cube. Real world pipelines also encounter complicating factors such as space and route constraints, plane displacement of the pipeline as well as a change in direction, and a need to solve anew at every bend. Len Williams tackled the problem with a Mathcad-based "ready reckoner" aid which turns input problems into output answers more quickly, transparently and easily than the manual or programmed alternatives.

"The solution was an exercise in matrix manipulation" comments Len. "The initial three dimensional bases needed to be set up, the matrices of transition calculated and then used to operate on the various bases and the vectors which represent the segments. Finally the angle that we needed to twist the first segment on the incoming pipe to bring the direction of the outgoing pipe into a plane parallel to that plane that it would have occupied if we had not twisted the segments relative to each other." Although he modestly describes himself as "not at all proficient", the worksheet is efficient and well documented, literally talking the user through solutions involving up to ten segments. This is greatly aided by the text-page nature of Mathcad, encouraging natural language approaches which facilitate speed and clarity. An opening table of values is followed progressively by matrix layouts, local bases and vectors, as Mathcad's flexible mix of text and symbolics clearly steps the user through full explanations of what the sheet is doing, and why, as intermediate and final values are computed.

Looking to the future, Len remarks that he would like to add diagrams or other visual illustrations, again using Mathcad's facilities or the bundled Smartsketch application, to further amplify and clarify the process for unfamiliar users. The whole sheet is a text-book example of the advantages offered by Mathcad's open, word processor approach over traditional spreadsheet or language-programmed approaches when it comes to the speedy development and communication of human-friendly mathematical solutions.