AC 2009-490: MATHCAD ENABLING OF ENGINEERING E-CONTENT ON KNOVEL

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Sasha Gurke was one of the co-founders of Knovel in 1999, having joined a predecessor company in 1996 as VP Product Development. In this position, Sasha has led the development of Knovel's award-winning interactive e-book library, focusing on product development, functional design, information architecture, search logic and production.

Prior to Knovel, Sasha spent 15 years with Chemical Abstract Service/American Chemical Society in various Product Development and Editorial capacities.

Sasha is a trained Chemist and Process Engineer with years of industrial and lab experience. His major contribution to Knovel’s success was application of this experience in the development of information products for applied scientists and engineers.

Mathcad Enabling of Engineering e-Content on Knovel

Abstract

Knovel recently released Mathcad-enabled *Roark's Formulas for Stress and Strain* and (Hicks) *Handbook of Civil Engineering Calculations*. The release of these titles represents a quantum leap from Knovel's standard interactivity such as tables, to a full scale engineering solution. Desktop 3rd party software (Mathcad© from Parametric Technology Corp.) has been seamlessly integrated with standard engineering content online. Mathcad is a Computer Aided Design platform with calculation, graphing, text formatting and reporting capabilities which can be used to transcribe engineering content, e.g., calculation examples. Challenges encountered during creation of this unique product, product features, expansion plans for the offering and initial customer response are discussed by an engineer who spearheaded the effort.

Brief Overview of Knovel

Knovel is an award-winning, Web-based library of e-references (e-books and databases) for applied scientists and engineers.

Knovel adds value to e-books by making them interactive. Interactive book tools include tables, graphs and equations. There are several interactive tools, including:

- *Graph Digitizer* for digitizing graphs displayed as calibrated raster images stored in Knovel database
- *Graph Plotter* for plotting graphs using X,Y coordinates stored in Knovel database
- *Equation Plotter* for calculating and plotting functions F=Y(X) stored in Knovel database
- *Phase Diagram Viewer* for determining phase composition of binary systems by digitizing diagrams displayed as calibrated raster images stored in Knovel database
- *Excel Spreadsheet* for calculating equations programmed in Excel
- *Interactive Tables* for sorting, filtering, etc. of tabular data stored in Knovel database.

Interactivity improves an engineer's productivity by enhancing searchability and allowing analysis and manipulation of otherwise static data. Knovel's interactive productivity tools are proprietary and programmed in Flash. We are currently replacing these with similar Mathematica engine-based tools programmed using Ajax technology.

Starting in 1999, we have digitized over 1800 STM titles from about 50 publishers including industry leaders such as Elsevier, Wiley, McGraw-Hill and Springer. The topics range across 20 subject areas, including chemistry, mechanical engineering, electronics, oil and gas, sustainable development and construction materials. Many titles, e.g., in the chemical industry safety area, are unique to Knovel and cannot be found anywhere else.

Some Knovel titles are multi-volume publications with the total number of pages exceeding 800,000 (this number does not include databases.) The collection is growing at a rate of 35-40 new titles per month.

Users can browse and simultaneously search all titles via a single interface. Basic and advanced searches are fast and optimized for technical users.

At the end of 2008, Knovel embarked on a new and exciting project: Mathcad-enabling Knovel content. Our first release is an introductory package for structural and civil engineers that includes two well known titles partially transcribed into Mathcad worksheets.

Knovel Mathcad Product

Engineers across all industries perform engineering calculations and document their design and analysis work. While performing these tasks, they often reference standard calculations, solutions and other pertinent information from titles such as *Roark's Formulas for Stress and Strain* and *(Hicks) Handbook of Civil Engineering Calculations*. Knovel introduced Mathcad-enabled versions of these two leading engineering reference titles to allow engineers to design and document engineering calculations with increased efficiency.

Mathcad is a desk-top Computer Aided Design (CAD) platform with calculation, graphing, text formatting and reporting capabilities and is produced by Parametric Technology Corp. In the Knovel Mathcad product it is seamlessly integrated with standard engineering content online by transcribing engineering calculations and design examples in the above titles. Using our precision search tools in an easy to use interface, Knovel search results identify examples that are fully interactive, integrate directly into Mathcad for easy data manipulation, and are available in U.S. Customary and Metric units.

There are several points of access to Mathcad worksheets in the Search and Browse modes. Users can access the worksheets and the corresponding PDF reports via links in the original source (see below), or access worksheets from the links in the reports.

determination of beam deflections. By superposition, the formulas can be made to apply to almost any type of loading and support. The use of the tabulated and fundamental formulas given in this article is illustrated in the following examples.

EXAMPLES US Customary US Customary Metric Metric

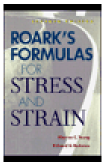
1. For a beam supported and loaded as shown in Fig. 8.2, it is required to determine the maximum tensile stress, maximum shear stress, and maximum compressive stress, assuming, first, that the beam is made of wood with section as shown in Fig. 8.2(a) second, that the beam is made of wood with section as shown in Fig. 8.2(b); and third that the beam is a 4-in, 7.7-lb steel I-beam.

Solution. By using the equations of equilibrium (Sec. 4.1), the left and right reactions are found to be 900 and 1500 lb, respectively. The shear and moment equations are therefore

$$(x = 0 \text{ to } x = 160): \quad V = 900 - 12x$$
$$M = 900x - 12x(\tfrac{1}{2}x)$$
$$(x = 160 \text{ to } x = 200): \quad V = 900 - 12x + 1500$$
$$M = 900x - 12x(\tfrac{1}{2}x) + 1500(x - 160)$$

Mathcad worksheets and PDF reports along with all the chapters of the books can be also accessed from the Table of Contents as users browse thought the site. A single click on the Filter button **Filter:** Knovel Math Documents conveniently exposes all Mathcad links by expanding the Table of Contents (see below).

Roark's Formulas for Stress and Strain (7th Edition) [Mathcad-enabled]



By: Young, Warren C.; Budynas, Richard G. © 2002 McGraw-Hill

Description: All examples in Part III: Formulas and Examples, over 75 in total, have been made interactive using Mathcad. Each example is available in US Customary and Metric units. Examples cover straight and curved beams, plates and shells. *[Mathcad 14.0 or higher is required.]*

Title Details | **Citation**

Filter: Close Knovel Math Documents

Table of Contents	Data (Records)	Text
Front Matter		Text
List of Tables		Text
Preface to the Seventh Edition		Text
Preface to the First Edition		Text
Table of Contents		Text
⊞ ***Part I. Introduction***		
⊞ ***Part II. Facts; Principles; Methods***		
⊟ ***Part III. Formulas and Examples***		
⊟ 7. Tension, Compression, Shear, and Combines Stress		Text
⊟ 7.1 Bar under Axial Tension (or Compression); Common Case		Text
Example 7.1.1 (US Customary Units)	Mathcad	Text
Example 7.1.1 (Metric Units)	Mathcad	Text
⊟ 7.2 Bar under Tension (or Compression); Special Cases		Text

Overall the design of Mathcad-enabled titles follows the standard design of all interactive content on Knovel. Clicking on a Mathcad link in the Table of Contents opens the application with the fully parameterized example (see below). To view it, users must have Mathcad 14.0 or higher installed on their PC.

Each Mathcad worksheet (see Example 16.2.1 from *Roark's Formulas of Stress and Strain* below) and corresponding PDF report exists in both US Customary and Metric units for a total of 4 files, i.e., native units (as found in the source document), one translated units to its counterpart and a PDF rendering of both Mathcad files. To access, the users must subscribe to the Mathcad-enabled title as it is not part of the standard Knovel subscription. Mathcad worksheets can be downloaded and modified without any restrictions. Users can copy and paste desired calculations from Knovel produced worksheets into their own Mathcad worksheets.

Searchability of Mathcad-enabled content has been enhanced by indexing the keyword '*mathcad'* for each page of Mathcad content. As a result, users can retrieve this content very precisely by a Boolean query containing this keyword, e.g., '*beam bending AND mathcad'*. To further assist users in browsing and searching Mathcad-enabled content, each case and example has been labeled with meaningful titles which include measurement system used.

Knovel Mathcad Solution. Copyright © 2009 Knovel Corp.

Roark's Formulas for Stress & Strain, Seventh Edition. Copyright © 2002 McGraw-Hill
Chapter 16: Dynamic and Temperature Stresses
16.2 Body in a Known State of Motion

EXAMPLE 16.2.1

▶ Disclaimer

▶ User Notices

The conical steel disk shown in section in **Fig. 16.4** rotates at 2500 rpm. To its rim it has attached buckets whose aggregate mass amounts to w = 0.75 lb/linear in of rim; this mass may be considered to be centered 30 in from the axis. It is desired to determine the stresses at a point 7 in from the axis.

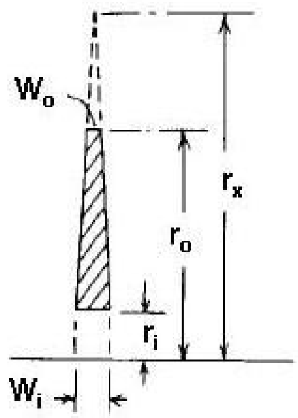


Fig. 16.4: Cross sectional view of the disk

Geometry

Mean radius: $R_m := 28 \cdot in$

Inner rim: $r_i := 4 \cdot in$

Outer rim: $r_o := 20 \cdot in$

Circumference: $r_r := 7 \cdot in$

Knovel began development of Mathcad enabled content in August of 2008. By mid 2009, we plan to develop 3 important titles:

- *Roark's Formulas for Stress and Strain* (7th Edition), 2002, McGraw-Hill
- *Handbook of Civil Engineering Calculations,* 1999, McGraw-Hill
- *Foundation Engineering Handbook - Design and Construction with the 2006 International Building Code*, 2007, McGraw-Hill

These titles represent our Civil/Structural Engineering offering. Future Mathcad-enabled packages will focus on Mechanical, Electrical, Environmental and Aerospace Engineering. Currently, Knovel is working on *Peterson's Stress Concentration Factors* (3rd Edition), 2008, John Wiley & Sons, and on updating *Handbook of Civil Engineering Calculations* (2nd Edition was published in 2007).

Much work has been done since the beginning of this project, including development of a Mathcad transcription specification, workflow and best practice documents, product design, improvements to the Knovel GUI and other software changes, building of a multinational team of dedicated engineers with appropriate skills to create and edit Mathcad content, and most importantly instituting rigorous quality management of the entire production process.

Many of the tasks associated with this project presented significant challenges. Below we discuss the two deemed most important: selecting the content for Mathcad integration and managing the product quality.

Selection of Titles for Knovel Mathcad Product

Most STM titles have mathematical formulae and equations. Some of them are theoretical or do not represent a complete engineering solution and therefore are of little value to practicing engineers. Others are used in specific calculations that could be applicable in the design and analysis of structures (such as buildings and bridges), electric devices and machines. The latter are often found in references used by generations of engineers and provide time-proven analytical engineering solutions. When made "live" or interactive, these calculations could result in huge time savings for engineers, while minimizing errors and improving record-keeping. Indeed, often an engineer has to merely input desired values to recalculate the equation or a whole series of equations with a single click of a mouse and have a ready-made report for sharing with colleagues and management.

Knovel's goal has been to provide interactive calculation tools along with the source text containing the calculations, allowing engineers to quickly implement a specific case while having access to all contextual information. In the case of Mathcad, we accomplished that goal by seamlessly integrating Mathcad worksheets with full text searchable e-books.

The first task in developing Mathcad-enabled content was the selection of the appropriate titles. The selection process consisted of several steps:

1. Using market analysis to choose the field of engineering
2. Indentifying books with content suitable for Mathcad integration
3. Evaluating these books for content quality
4. Deciding on processing priority

Market analysis revealed 4 main areas with a need for Mathcad-enabled content (listed in the order of priority):

1. Mechanical Engineering
    a. Civil
    b. Structural
    c. Machine design
2. Electrical Engineering
3. Aerospace Engineering
4. Environmental Engineering

Next, we indentified titles with a large number of practical calculation examples by searching Knovel and amazon.com, conducting user surveys, analyzing references and Mathcad content on the web, and analyzing Mathcad content in the Parametric Technologies engineering library. The goal was to select well-regarded books that went through multiple editions. Some of the books identified were not available for a variety of reasons, e.g., being out of print.

The value of content was evaluated based on the usage statistics on Knovel (average frequency of access per month), book rating and reviews on amazon.com, detailed evaluation of content by Knovel engineers and user feedback. The latter required building a prototype to demonstrate the concept to the users, who then completed a survey on their experience.

A portion of the resulting list of titles is shown in the table below:

Knovel Usage	Book Title	Author(s)	Publisher	Pub. Year
12922	Roark's Formulas for Stress and Strain (7th Edition)	Young, W.C.; Budynas, R.G.	McGraw-Hill	2002
4023	Handbook of Civil Engineering Calculations	Hicks, T.G.	McGraw-Hill	1999
1683	Foundation Engineering Handbook - Design and Construction with the 2006 International Building Code	Day, Robert W.	McGraw-Hill	2006
13382	Peterson's Stress Concentration Factors (3rd Edition)	Pilkey, Walter D., Pilkey, Deborah F.	John Wiley & Sons	2008
4207	Building Design and Construction Handbook (6th Edition)	Merritt, F.S.; Ricketts, J.T.	McGraw-Hill	2001
2767	AIAA Aerospace Design Engineers Guide (5th Edition)	AIAA Design Engineering Technical Committee	John Wiley & Sons	2005
5456	Structural Steel Designer's Handbook (3rd Edition)	Brockenbrough, R.L.; Merritt, F.S.	McGraw-Hill	2005
N/A	Structural Dynamics: Theory and Computation	William E. Leigh, Mario Paz	Springer	2006
5065	Machine Design Databook (2nd Edition)	Lingaiah, K.	McGraw-Hill	2003
17915	Machinery's Handbook (27th edition)	Oberg, Erik; Jones, Franklin D.; Horton, Holbrook L.; Ryffel, Henry H.	Industrial Press	2004
N/A	Standard Handbook of Engineering Calculations (4th edition)	Hicks, T.G.	McGraw-Hill	2004
N/A	The Seismic Design Handbook (2nd Edition)	Farzad Naeim	Springer	2001
N/A	Advanced Mechanics of Materials (6th Edition)	Arthur P. Boresi & Richard J. Schmidt	John Wiley & Sons	2002

<u>Quality of the Knovel Mathcad Product</u>

There is a substantial difference between the Knovel product and traditional engineering software. Knovel does not produce stand-alone engineering software. Knovel is an online aggregator of full text and field searchable content available mostly in PDF text and interactive table formats. The mission of Knovel is to provide end users with reliable and useful engineering information. Some information is transcribed with 3rd party software such as Mathcad, while other information is integrated with Knovel's own interactive tools such as the Graph Plotter. The purpose is to help users analyze and use retrieved information more efficiently and precisely. The tools we use are not built around some special algorithms requiring individual validation. Instead, our tools are universal and intended for step-by-step realization of algorithms found in the original source/content. To ensure reliable realization of these algorithms in the product, they are painstakingly tested in each step of the production process before being released. Development and implementation of testing and quality assurance procedures represented the greatest challenge during the Mathcad integration project. We have overcome it successfully! The procedures for testing and assuring the quality of Mathcad enabled content are described below.

1. Managing Quality of Mathcad Transcription Process

The process of transcribing a case from the original source into a Mathcad worksheet was designed with multiple quality checks (see **Workflow Diagram** below) that leverage available skill sets. The transcription was performed according to detailed specification and best practices that emphasize consistency of the product and comprehensive use of the original sources. Ensuring the quality has been a challenge because of the complexity of the product and because the work has been done by a multinational team of 14 engineers in USA, India and Russia. In the **Appendix** are excerpts from the best practices document. This and other documentation was developed by professional engineers with many years of Mathcad experience.

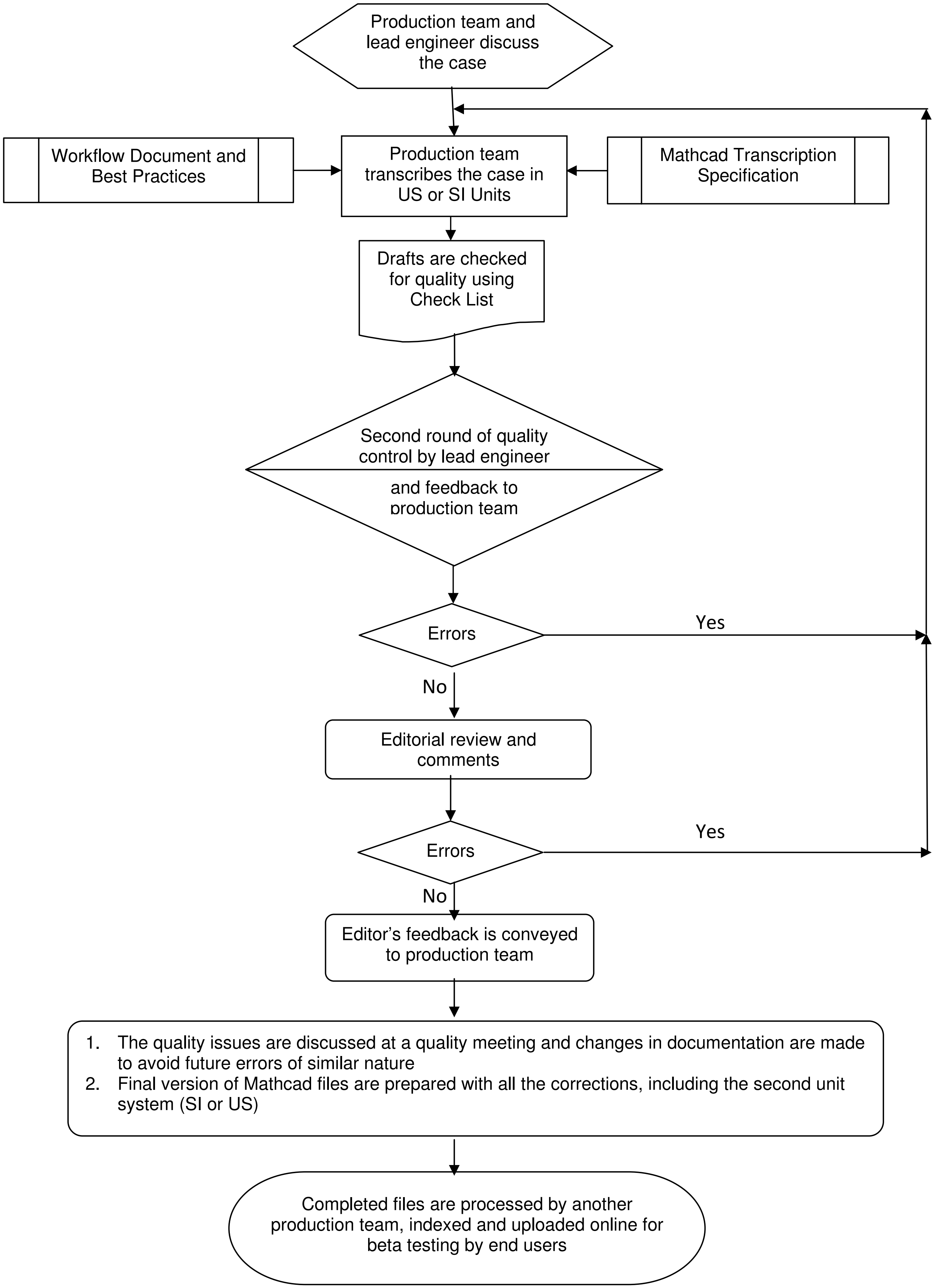
The transcription process is just one stage in the production of the Mathcad-enabled Knovel product. Other stages include integration of Mathcad worksheets with the book in PDF format, indexing and final product testing. Each stage of production consists of multiple steps. For example, the integration process includes insertion of hotlinks from source text to Mathcad worksheets and expanding table of contents to include links to Mathcad worksheets.

Knovel implemented quality control checks on every step of each stage of the production process. One such checklist, developed for the drafting step of Mathcad transcription process, is given below.

Transcription Checklist

1. Check text both manually and using the Tools/Spelling menu item to correct formatting, punctuation, spelling and typographical errors (typos).
2. Check that all variable names are consistent with the book and the Mathcad figures.
3. Check that narrow dot exists for all multiplication signs between figures and units.
4. Check that the example has been generalized properly:
    a. There are no values in text regions, only variables
    b. Textual outputs have been generalized.
5. Check that the arrows and text are sized properly in the figures and the text is placed at the correct location
6. Check all units are consistent with the standard table.
7. Check that the number of digits after decimal point is appropriate for all results.
8. Check if all references to textbook equations have been made.
9. Check that all equations are vertically aligned.

Transcription Workflow Diagram



2. Inherent Soundness of Used Algorithms

The core of Knovel's collection is comprised of titles by well known authors published by reputable STM publishers. Many of these titles, first published many years ago, have gone through multiple editions, becoming well trusted "bibles" for generations of engineers.

Established reputation in the engineering community is one of the main criteria considered during selection of the content for Mathcad transcription. Other criteria considered are customer feedback and popularity as expressed by the frequency of online access. Good examples of the titles that meet these criteria are

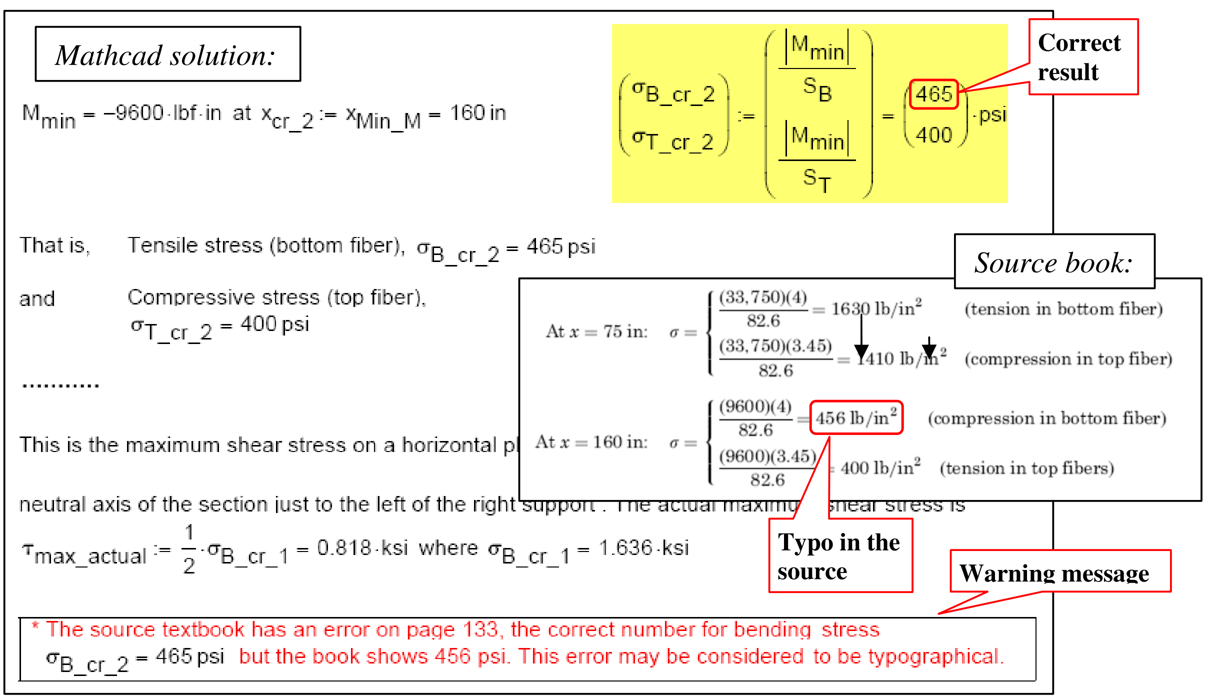
- *Roark's Formulas for Stress and Strain* (7th Edition), 2002, McGraw-Hill
- *Peterson's Stress Concentration Factors* (3rd Edition), 2008, John Wiley & Sons
- *Handbook of Civil Engineering Calculations* (2nd Edition), 2007, McGraw-Hill

To a great extent, this rigorous selection process guaranties the inherent soundness of the algorithms used in the development of the Knovel Mathcad product.

3. Verification of Calculation Algorithms

Even these trusted publications contain random misprints and typos in the equations resulting from inadequate technical editing during multiple editions and revisions by different authors. These errors are easily revealed during realization of the algorithms in Mathcad because they lead either to unexpected results during numeric and graphic verification or by the failure of the Mathcad software to calculate. Overall, we found these types of errors in about 10% of the transcribed cases.

In most cases, errors in the original source are highlighted in Mathcad worksheets in red with an editorial comment explaining the error as shown below.



According to specification, all algorithms in the original text are verified multiple times. Initially, each algorithm is verified by an engineer responsible for the transcription of a particular case. Since each algorithm in the Knovel Mathcad product is realized numerically, this verification is very accurate.

Subsequent verification is performed by an independent editor who is an engineer with significant experience in the field and in Mathcad programming. During this step, the algorithm is re-examined step-by-step for a second time.

Creation of two Mathcad worksheets for the same case in two systems of units of measurement, US Customary and Metric, provides additional verification of the algorithm.

In some cases, this rigorous quality control process results in detection of serious errors such as those shown in ***Fig. 1*** below. In this and similar cases, the magnitude of the error is so significant that highlighting it (in red with editorial comment) becomes impractical for formatting reasons.

4. Comparing Numerical Solution in Original Source with Mathcad Solution

In most Knovel Mathcad products, e.g., *Handbook of Civil Engineering Calculations*, almost 100% of cases have numerical solutions in the original source. The boundary conditions given in these cases are perfectly suited for validation of the algorithms in the Mathcad implementation.

Most algorithms in the original source are realized in a step-by-step fashion. This allows validation of both the final and the intermediate results of the Mathcad implementation. The results deviating in excess of the rounding error (usually <5%) trigger in-depth analysis of the cause and correction of the error(s) in the Mathcad worksheet.

If no error is found in the Mathcad worksheet, we look for a possible algorithmic or calculation error in the original source. If an error is found or algorithm in the original source is deemed to be suspicious, the algorithm is corrected but only after it is verified against another source. In some cases the intermediate numeric results are verified independently of the final results. ***Figs. 2-7*** below illustrate this approach.

5. Use of Multiple Algorithms to Validate Solutions

Validation of the results is the most important aspect of engineering calculations. Therefore, a significant portion of the solutions given in original sources is obtained by at least two different methods. The results are compared to validate the solution as demonstrated in ***Figs. 2-4***.

In addition, some solutions include calculations specifically intended to validate the results. These are shown in ***Figs. 5-7***. Naturally, these cases are transcribed in full, including alternative and validation calculations, so that end users can visually compare the results.

Often in these cases, we insert a function helping compare the results of the primary calculation with those of verification. Below is an example such a function.

Check: =if (|A-B|<Δ*|A|, "Satisfactory", "Not Satisfactory")

Where:

|A-B| - absolute value of the difference between of the results of the primary and validation calculations,

Δ - assumed precision of calculations (from 0.01, if calculations are done using exact equations, e.g., trigonometric, to 0.10, if calculations are done using empirical equations),
|A| - absolute value of the result of primary calculation.

The results of calculations using this function are provided to assist the users in verification of their own results. See ***Fig. 7*** as an example.

6. Validation of Solutions using 3^{rd} Party Software

In a few cases when the results caused further doubt, we validated the solutions using 3^{rd} party software. For example, we used existing Mathsoft solutions and FEM software to validate a number of cases from *Roark's*.

7. Customizing Validation Procedures

There are several types of engineering solutions that were transcribed into Mathcad by the Knovel production team. Each type required various validation procedures and test methods, which are listed below (some are described in more detail in the preceding sections).

- *Dimension control*. Dimension control allows easy detection and corrections of most misprints and typos in the source text as shown in ***Fig. 12***.
- *Comparing results with numerical solution given in the original text*. This type of validation is the most simple, reliable and widely used. It was used everywhere when applicable, e.g., for *Handbook of Civil Engineering Calculations* where all examples had numerical solutions (see ***Figs. 2-7***).
- *Verification of intermediate calculations.* This method was used in every case where intermediate results were available in the source text. For example, comparing calculation results for general plate functions and constants in Table 11.2 in *Roark's Formulas for Stress and Strain* on p. 457 with those obtainable for Table 11.1 on p. 455 resulted in detection of a typo in the equation for the constant L_1 on p. 458 ($\ln(r_0/a)$ should be replaced by $\ln(a/r_0)$). A typo in the equation for the function F_1 on p. 457 (instead of $(1+\nu*a)/2$ there should be $(1+\nu)/2$) was found and corrected early in the calculation as a result of dimensional mismatch of the sum terms (s*ee* ***Fig. 1***).
- *Validation of algorithms at boundary conditions.*
- *Validation of algorithms at minimum and maximum values of variables and under special conditions*.
- *Visual validation of calculation results presented in graphic form*. Most Mathcad worksheets have graphic representation of the results such as Shear and Moment Diagrams.
- *Comparing Mathcad calculation results with results obtained using other 3^{rd} party software.*

Below is an example of validation for the Mathcad solution of the case 11.2.8h from *Roark's Formulas for Stress and Strain*, p. 487. No numeric solutions exist for this and other cases from the tables in Chapters 8 through 17 in this source. The algorithm for the case affords:

- Calculating general plate functions and constants with equations on pp. 457-458 (see ***Fig. 8***)
- Calculating boundary conditions with equation on p. 487 (see ***Fig. 9***)
- Determining the function for calculation of deflections, slopes, moments, and shear forces with equations on p. 484 (see ***Fig. 10***)

- Presenting calculation results in graphic and tabular formats (see ***Fig. 11***)

The validation sequence for this case is as follows:

- Verify correctness of dimensions of calculation results to validate the function (see ***Fig. 12***)
- Compare calculation results for general plate functions and constants with results in Table 11.1, p. 455 (see ***Fig. 13***)
- Compare calculation results for moments and shear for the supporting cross sections **a** and **b** with results obtained with equations on p. 484 using numeric coefficients provided for the case 8h in Table 11.2 (see ***Fig. 14***)
- Check if the shape of bending curves is as expected, paying special attention to their behavior at boundary conditions (see ***Fig. 11***)
- Test the behavior of functions in special cases. For this problem, the special case is temperature gradient along the plate length (see ***Fig. 15***)
- Verify Knovel Mathcad results against PTC/Mathsoft results if available (see ***Figs. 16*** and ***17***)

Conclusions

The main challenges encountered during the development of the Knovel Mathcad product have been the selection of appropriate content, finding engineers with adequate skill set to produce and edit Mathcad worksheets and ensuring high quality of the products.

Although foolproof quality control does not exist, we hope that all the measures described above result in the best quality Mathcad product available on the market. The final judge will be the users.

Recognizing the very important role that users play in testing and improving the quality of the products, Knovel has instituted a rigorous alpha and beta testing program for the Mathcad product. During several months of testing, users suggested a number of improvements that are currently being implemented.

Source book:
Page 457:

General Plate Functions and Constants

$$F_1 = \frac{1+\nu a}{2}\frac{b}{r}\ln\frac{r}{b} + \frac{1-\nu}{4}\left(\frac{r}{b}-\frac{b}{r}\right)$$

$$F_2 = \frac{1}{4}\left[1-\left(\frac{b}{r}\right)^2\left(1+2\ln\frac{r}{b}\right)\right]$$

Simple typo

Page 458:

TABLE 11.2 Formulas for flat circular plates

Typo found later

$$L_1 = \frac{1+\nu}{2}\frac{r_o}{a}\ln\frac{r_0}{a} + \frac{1-\nu}{4}\left(\frac{a}{r_o}-\frac{r_o}{a}\right)$$

$$L_2 = \frac{1}{4}\left[1-\left(\frac{r_o}{a}\right)^2\left(1+2\ln\frac{a}{r_o}\right)\right]$$

$$L_3 = \frac{r_o}{4a}\left\{\left[\left(\frac{r_o}{a}\right)^2+1\right]\ln\frac{a}{r_o}+\left(\frac{r_o}{a}\right)^2-1\right\}$$

Mathcad solution:

Fixed

$$F_{plt}(r,b) \equiv \begin{bmatrix} \left(\frac{1+\nu}{2}\right)\cdot\left(\frac{b}{r}\right)\cdot\ln\left(\frac{r}{b}\right)+\left(\frac{1-\nu}{4}\right)\cdot\left(\frac{r}{b}-\frac{b}{r}\right) \\ \frac{1}{4}\cdot\left[1-\left(\frac{b}{r}\right)^2\cdot\left(1+2\cdot\ln\left(\frac{r}{b}\right)\right)\right] \\ \frac{b}{4\cdot r}\cdot\left[\left[\left(\frac{b}{r}\right)^2+1\right]\cdot\ln\left(\frac{r}{b}\right)+\left(\frac{b}{r}\right)^2-1\right] \\ \frac{1}{2}\cdot\left[(1+\nu)\cdot\frac{b}{r}+(1-\nu)\cdot\frac{r}{b}\right] \\ \frac{1}{2}\cdot\left[1-\left(\frac{b}{r}\right)^2\right] \\ \frac{b}{4\cdot r}\cdot\left[\left(\frac{b}{r}\right)^2-1+2\cdot\ln\left(\frac{r}{b}\right)\right] \\ \frac{1}{2}\cdot\left(1-\nu^2\right)\cdot\left(\frac{r}{b}-\frac{b}{r}\right) \\ \frac{1}{2}\cdot\left[1+\nu+(1-\nu)\cdot\left(\frac{b}{r}\right)^2\right] \\ \frac{b}{r}\cdot\left[\left(\frac{1+\nu}{2}\right)\cdot\ln\left(\frac{r}{b}\right)+\left(\frac{1-\nu}{4}\right)\cdot\left[1-\left(\frac{b}{r}\right)^2\right]\right] \end{bmatrix}$$

$$F(r) \equiv F_{plt}(r,b)$$

$$C \equiv F(a)$$

$$G(r) \equiv F_{plt}(r,r_o)\cdot(r>r_o)$$

$$L \equiv G(a)$$

Fig. 1. Typos in *Roark's Formulas for Stress and Strain*, Table 11.2, pp. 457-458. The first, simple typo was detected immediately because it makes numeric solution impossible. The second typo was detected by comparing intermediate results with the values obtained from Table 11.1.

Source book:

Developing the area equations yields

$$\text{Area} = \tfrac{1}{2}[d_2(h_1 - h_3) + d_3(h_2 - h_4) + \cdots + d_{n-1}(h_{n-2} - h_n) + d_n(h_{n-1} + h_n)] \quad (6)$$

Or, **Method 1** **Method 2**

$$\text{Area} = \tfrac{1}{2}[h_1 d_2 + h_2 d_3 + h_3(d_4 - d_2) + h_4(d_5 - d_3) + \cdots + h_n(d_n - d_{n-1})] \quad (7)$$

2. Determine the area, using Eq. 6

Thus, area = ½[25(29.8 − 93.2) + 60(64.6 − 58.1) + 75(93.2 − 28.5) + 110(58.1 + 28.5)] = 6590 ft^2 (612.2 m^2). **Result 1**

3. Determine the area, using Eq. 7

Thus, area = ½[29.8 × 25 + 64.6 × 60 + 93.2(75 − 25) + 58.1(110 − 60) + 28.5(110 − 75)] = 6590 ft^2 (612.2 m^2). Hence, both equations yield the same result. The second equation has a distinct advantage over the first because it has only positive terms. **Result 2**

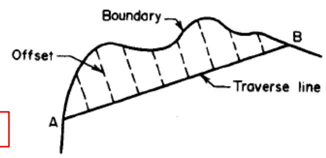


FIGURE 7. Tract with irregular boundary.

Mathcad solution:

nmax := rows(d)

$$\text{Area}_1 := \frac{1}{2}\left[\sum_{n=1}^{nmax-2}\left[d_{n+1}\cdot(h_n - h_{n+2})\right] + d_{nmax}\cdot(h_{nmax-1} + h_{nmax})\right] \quad \text{[eq.(6) p.5.7]}$$

Method 1 **Method 2**

$$\text{Area}_2 := \frac{1}{2}\left[\sum_{n=3}^{nmax-1}\left[h_n\cdot(d_{n+1} - d_{n-1})\right] + h_1\cdot d_2 + h_2\cdot d_3 + h_{nmax}\cdot(d_{nmax} - d_{nmax-1})\right] \quad \text{[eq.(7) p.5.7]}$$

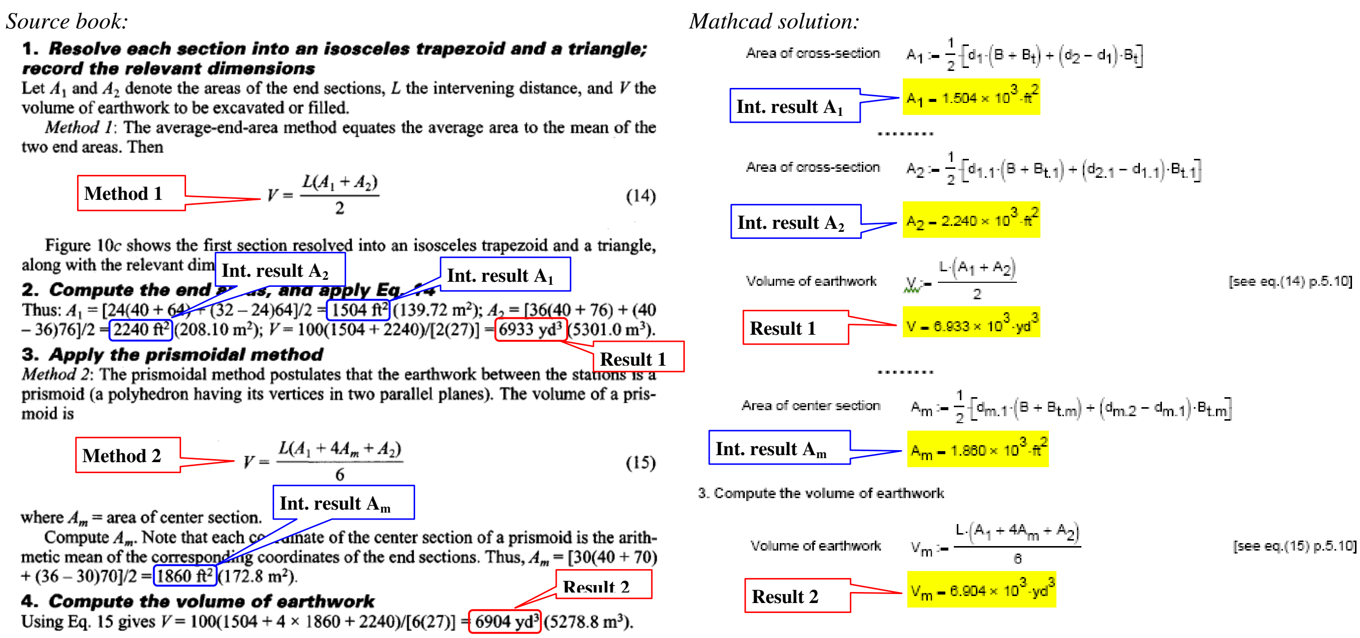
2. Determine the area, using Eq. 6

$\text{Area}_1 = 6.592 \times 10^3 \cdot ft^2$ **Result 1**

3. Determine the area, using Eq. 7

$\text{Area}_2 = 6.592 \times 10^3 \cdot ft^2$ **Result 2**

Fig. 2. *Handbook of Civil Engineering Calculations*, p. 5.7. This example demonstrates Mathcad results obtained by two different methods given in the source book. Mathcad results are the same and match with results in the source.


Source book:

1. Resolve each section into an isosceles trapezoid and a triangle; record the relevant dimensions

Let A_1 and A_2 denote the areas of the end sections, L the intervening distance, and V the volume of earthwork to be excavated or filled.

Method 1: The average-end-area method equates the average area to the mean of the two end areas. Then

Method 1
$$V = \frac{L(A_1 + A_2)}{2} \quad (14)$$

Figure 10*c* shows the first section resolved into an isosceles trapezoid and a triangle, along with the relevant dim

Int. result A_2 — Int. result A_1

2. Compute the end ... and apply Eq. 14

Thus: A_1 = [24(40 + 64) + (32 – 24)64]/2 = 1504 ft² (139.72 m²); A_2 = [36(40 + 76) + (40 – 36)76]/2 = 2240 ft² (208.10 m²); V = 100(1504 + 2240)/[2(27)] = 6933 yd³ (5301.0 m³).

Result 1

3. Apply the prismoidal method

Method 2: The prismoidal method postulates that the earthwork between the stations is a prismoid (a polyhedron having its vertices in two parallel planes). The volume of a prismoid is

Method 2
$$V = \frac{L(A_1 + 4A_m + A_2)}{6} \quad (15)$$

Int. result A_m

where A_m = area of center section.

Compute A_m. Note that each coordinate of the center section of a prismoid is the arithmetic mean of the corresponding coordinates of the end sections. Thus, A_m = [30(40 + 70) + (36 – 30)70]/2 = 1860 ft² (172.8 m²).

Result 2

4. Compute the volume of earthwork

Using Eq. 15 gives V = 100(1504 + 4 × 1860 + 2240)/[6(27)] = 6904 yd³ (5278.8 m³).

Mathcad solution:

Area of cross-section $A_1 := \frac{1}{2}\left[d_1\cdot(B + B_t) + (d_2 - d_1)\cdot B_t\right]$

Int. result A_1 — $A_1 = 1.504 \times 10^3 \cdot ft^2$

....

Area of cross-section $A_2 := \frac{1}{2}\left[d_{1.1}\cdot(B + B_{t.1}) + (d_{2.1} - d_{1.1})\cdot B_{t.1}\right]$

Int. result A_2 — $A_2 = 2.240 \times 10^3 \cdot ft^2$

Volume of earthwork $V := \frac{L\cdot(A_1 + A_2)}{2}$ [see eq.(14) p.5.10]

Result 1 — $V = 6.933 \times 10^3 \cdot yd^3$

....

Area of center section $A_m := \frac{1}{2}\left[d_{m.1}\cdot(B + B_{t.m}) + (d_{m.2} - d_{m.1})\cdot B_{t.m}\right]$

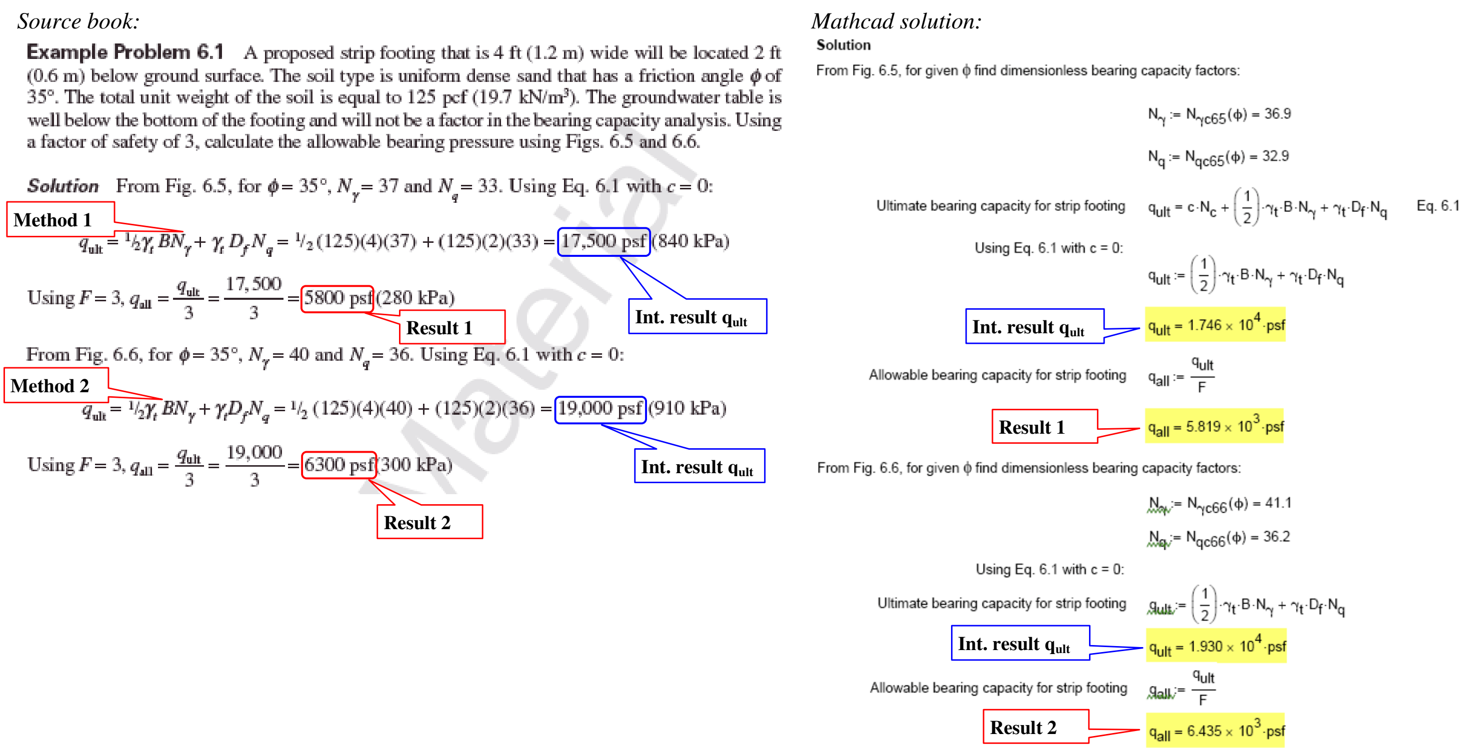
Int. result A_m — $A_m = 1.860 \times 10^3 \cdot ft^2$

3. Compute the volume of earthwork

Volume of earthwork $V_m := \frac{L\cdot(A_1 + 4A_m + A_2)}{6}$ [see eq.(15) p.5.10]

Result 2 — $V_m = 6.904 \times 10^3 \cdot yd^3$

Fig. 3. *Handbook of Civil Engineering Calculations*, p. 5.10. This example shows the results obtained by two different methods given in the source. The results have been compared among themselves and with the source. Intermediate results have been verified as well.



Source book:

Example Problem 6.1 A proposed strip footing that is 4 ft (1.2 m) wide will be located 2 ft (0.6 m) below ground surface. The soil type is uniform dense sand that has a friction angle ϕ of 35°. The total unit weight of the soil is equal to 125 pcf (19.7 kN/m³). The groundwater table is well below the bottom of the footing and will not be a factor in the bearing capacity analysis. Using a factor of safety of 3, calculate the allowable bearing pressure using Figs. 6.5 and 6.6.

Solution From Fig. 6.5, for $\phi = 35°$, $N_\gamma = 37$ and $N_q = 33$. Using Eq. 6.1 with $c = 0$:

Method 1

$$q_{ult} = \tfrac{1}{2}\gamma_t B N_\gamma + \gamma_t D_f N_q = \tfrac{1}{2}(125)(4)(37) + (125)(2)(33) = 17{,}500 \text{ psf } (840 \text{ kPa})$$

Int. result q_{ult}

Using $F = 3$, $q_{all} = \dfrac{q_{ult}}{3} = \dfrac{17{,}500}{3} = 5800 \text{ psf } (280 \text{ kPa})$

Result 1

From Fig. 6.6, for $\phi = 35°$, $N_\gamma = 40$ and $N_q = 36$. Using Eq. 6.1 with $c = 0$:

Method 2

$$q_{ult} = \tfrac{1}{2}\gamma_t B N_\gamma + \gamma_t D_f N_q = \tfrac{1}{2}(125)(4)(40) + (125)(2)(36) = 19{,}000 \text{ psf } (910 \text{ kPa})$$

Int. result q_{ult}

Using $F = 3$, $q_{all} = \dfrac{q_{ult}}{3} = \dfrac{19{,}000}{3} = 6300 \text{ psf } (300 \text{ kPa})$

Result 2

Mathcad solution:

Solution

From Fig. 6.5, for given ϕ find dimensionless bearing capacity factors:

$N_\gamma := N_{\gamma c65}(\phi) = 36.9$

$N_q := N_{qc65}(\phi) = 32.9$

Ultimate bearing capacity for strip footing $q_{ult} = c \cdot N_c + \left(\frac{1}{2}\right) \cdot \gamma_t \cdot B \cdot N_\gamma + \gamma_t \cdot D_f \cdot N_q$ Eq. 6.1

Using Eq. 6.1 with c = 0:

$q_{ult} := \left(\frac{1}{2}\right) \cdot \gamma_t \cdot B \cdot N_\gamma + \gamma_t \cdot D_f \cdot N_q$

Int. result q_{ult} $q_{ult} = 1.746 \times 10^4 \cdot psf$

Allowable bearing capacity for strip footing $q_{all} := \dfrac{q_{ult}}{F}$

Result 1 $q_{all} = 5.819 \times 10^3 \cdot psf$

From Fig. 6.6, for given ϕ find dimensionless bearing capacity factors:

$N_\gamma := N_{\gamma c66}(\phi) = 41.1$

$N_q := N_{qc66}(\phi) = 36.2$

Using Eq. 6.1 with c = 0:

Ultimate bearing capacity for strip footing $q_{ult} := \left(\frac{1}{2}\right) \cdot \gamma_t \cdot B \cdot N_\gamma + \gamma_t \cdot D_f \cdot N_q$

Int. result q_{ult} $q_{ult} = 1.930 \times 10^4 \cdot psf$

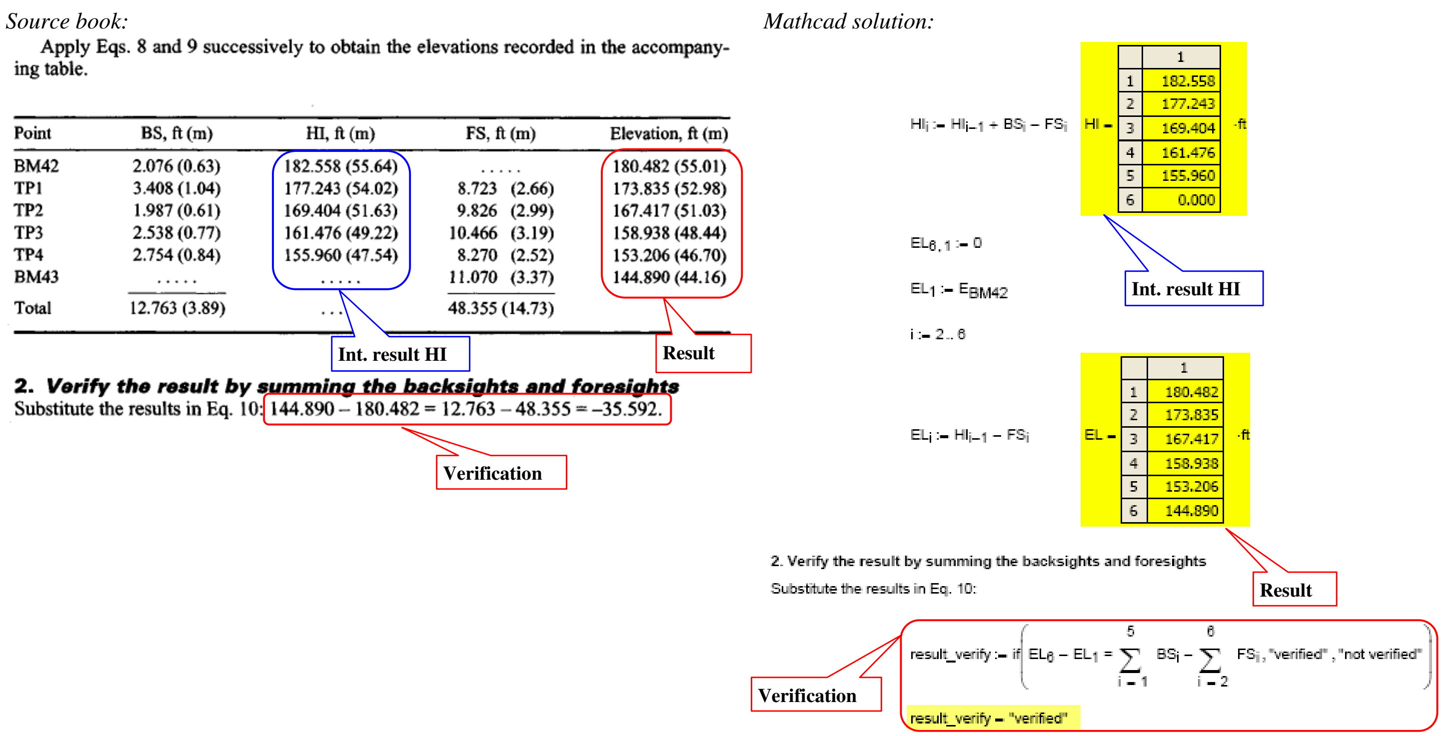
Allowable bearing capacity for strip footing $q_{all} := \dfrac{q_{ult}}{F}$

Result 2 $q_{all} = 6.435 \times 10^3 \cdot psf$

Fig. 4. *Foundation Engineering Handbook*, p. 6.7. This example shows the results obtained by two different methods given in the source. The results have been compared among themselves and with the source. Intermediate results have been verified as well. The divergence between the original and Mathcad results is due to an error caused by the method of calculation of coefficients. They were obtained by interpolation using an array of points resulting from digitization of the graph. Point coordinates were verified by repeated digitization resulting in ≤1.5% error.

Source book:

Mathcad solution:



Apply Eqs. 8 and 9 successively to obtain the elevations recorded in the accompanying table.

Point	BS, ft (m)	HI, ft (m)	FS, ft (m)	Elevation, ft (m)
BM42	2.076 (0.63)	182.558 (55.64)	. . . . .	180.482 (55.01)
TP1	3.408 (1.04)	177.243 (54.02)	8.723 (2.66)	173.835 (52.98)
TP2	1.987 (0.61)	169.404 (51.63)	9.826 (2.99)	167.417 (51.03)
TP3	2.538 (0.77)	161.476 (49.22)	10.466 (3.19)	158.938 (48.44)
TP4	2.754 (0.84)	155.960 (47.54)	8.270 (2.52)	153.206 (46.70)
BM43	. . . . .	. . . . .	11.070 (3.37)	144.890 (44.16)
Total	12.763 (3.89)	. . .	48.355 (14.73)	

2. Verify the result by summing the backsights and foresights

Substitute the results in Eq. 10: 144.890 – 180.482 = 12.763 – 48.355 = –35.592.

Fig. 5. *Handbook of Civil Engineering Calculations*, p. 5.8. This example demonstrates verification of the results using the verification algorithm available in the source. In addition, intermediate and final results have been compared with the source. In this particular case, the results are available as an array.

Source book:

Calculating the azimuth of the body yields

$$\tan^2 \tfrac{1}{2} Z = \frac{\sin (S - L) \sin (S - h)}{\cos S \cos (S - p)} \qquad (16)$$

where L = latitude of site; h = altitude of star; p = polar distance = 90° – declination; $S = \frac{1}{2}(L + h + p)$; L = 41°20′; h = 46°48′; p = 90° – 7°58′ = 82°02′; $S = \frac{1}{2}(L + h + p)$ = 85°05′; $S - L$ = 43°45′; $S - h$ = 38°17′; $S - p$ = 3°03′.

Then

log sin 43°45′	=		9.839800
log sin 38°17′			9.792077
			9.631877
log cos 85°05′	=	8.933015	
log cos 3°03′	=	9.999384	8.932399
2 log tan ½Z	=		0.699478
log tan ½Z	=		0.349739
½Z	=	65°55′03.5″	Z = 131°50′07″

Result

Mathcad solution:

$$\tan\left(\frac{1}{2}\cdot Z\right)^2 = \frac{\sin(S-L)\cdot\sin(S-h)}{\cos(S)\cdot\cos(S-p)}$$ [see eq.(16) p.5.13]

Thus Azimuth of the body $Z := 2\cdot\operatorname{atan}\left(\sqrt{\frac{\sin(S-L)\cdot\sin(S-h)}{\cos(S)\cdot\cos(S-p)}}\right)$

$$Z = \begin{pmatrix} 131 \\ 50 \\ 7 \end{pmatrix} \cdot \text{DMS}$$

Result

Verification:

2. Verify the solution by calculating Z in an alternative manner

To do this, introduce an auxiliary angle M, defined by

$$\cos^2 M = \frac{\cos p}{\sin h \sin L} \qquad (17)$$

Then

$$\cos (180° - Z) = \tan h \tan L \sin^2 M \qquad (18)$$

Then

log cos 82°02′	=		9.141754
log sin 46°48′	=	9.862709	
log sin 41°20′	=	9.819832	9.682541
2 log cos M	=		9.459213
log cos M	=		9.729607
log sin M	=		9.926276
2 log sin M	=		9.85[illegible]
log tan 46°48′	=		0.02[illegible]
log tan 41°20′	=		9.9[illegible]262
log cos (180° – Z)	=		9.8241 19
		Z = 131°50′07″, as before	

Result

2. Verify the solution by calculating Z in an alternative manner

To do this, introduce an auxiliary angle M, defined by

$$\cos(M)^2 = \frac{\cos(p)}{\sin(h)\cdot\sin(L)}$$ [see eq.(17) p.5.13]

Then $\cos(180° - Z) = \tan(h)\cdot\tan(L)\cdot\sin(M)^2$ [see eq.(18) p.5.13]

Then $\cos(180° - Z) = \tan(h)\cdot\tan(L)\cdot\left(1 - \frac{\cos(p)}{\sin(h)\cdot\sin(L)}\right)$

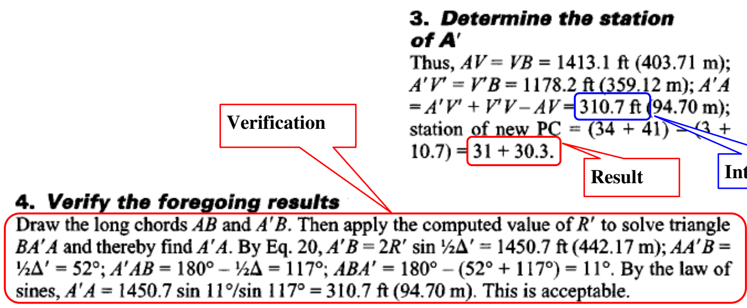
Azimuth of the body $Z := 180° - \operatorname{acos}\left[\tan(h)\cdot\tan(L)\cdot\left(1 - \frac{\cos(p)}{\sin(h)\cdot\sin(L)}\right)\right]$

$$Z = \begin{pmatrix} 131 \\ 50 \\ 7 \end{pmatrix} \cdot \text{DMS}$$

Result

Fig. 6. *Handbook of Civil Engineering Calculations*, p. 5.11. In this example, the results were obtained by two methods - primary and verification and Mathcad results have been compared among themselves and with the source.

Source book:



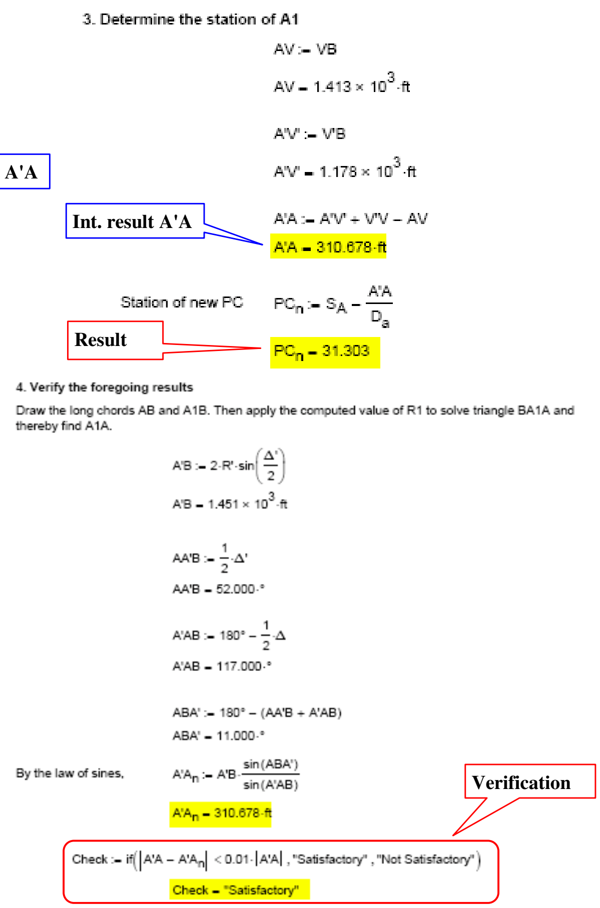
3. Determine the station of A′

Thus, $AV = VB$ = 1413.1 ft (403.71 m); $A'V' = V'B$ = 1178.2 ft (359.12 m); $A'A = A'V' + V'V - AV$ = 310.7 ft (94.70 m); station of new PC = (34 + 41) − (3 + 10.7) = 31 + 30.3.

4. Verify the foregoing results

Draw the long chords AB and $A'B$. Then apply the computed value of R' to solve triangle $BA'A$ and thereby find $A'A$. By Eq. 20, $A'B = 2R' \sin \frac{1}{2}\Delta'$ = 1450.7 ft (442.17 m); $AA'B = \frac{1}{2}\Delta'$ = 52°; $A'AB = 180° - \frac{1}{2}\Delta$ = 117°; ABA' = 180° − (52° + 117°) = 11°. By the law of sines, $A'A$ = 1450.7 sin 11°/sin 117° = 310.7 ft (94.70 m). This is acceptable.

Mathcad solution:



3. Determine the station of A1

AV := VB

AV = 1.413 × 10^3 · ft

A'V' := V'B

A'V' = 1.178 × 10^3 · ft

A'A := A'V' + V'V − AV

A'A = 310.678 · ft

Station of new PC $PC_n := S_A - \frac{A'A}{D_a}$

$PC_n = 31.303$

4. Verify the foregoing results

Draw the long chords AB and A1B. Then apply the computed value of R1 to solve triangle BA1A and thereby find A1A.

$A'B := 2 \cdot R' \cdot \sin\left(\frac{\Delta'}{2}\right)$

A'B = 1.451 × 10^3 · ft

$AA'B := \frac{1}{2} \cdot \Delta'$

AA'B = 52.000 · °

$A'AB := 180° - \frac{1}{2} \cdot \Delta$

A'AB = 117.000 · °

ABA' := 180° − (AA'B + A'AB)

ABA' = 11.000 · °

By the law of sines, $A'A_n := A'B \cdot \frac{\sin(ABA')}{\sin(A'AB)}$

$A'A_n = 310.678 \cdot ft$

Check := if(|A'A − A'A_n| < 0.01·|A'A|, "Satisfactory", "Not Satisfactory")

Check = "Satisfactory"

In this example, validation of the results is done using an algorithm provided in the original source. The result of validation is output in text format. In addition, the final and intermediate results of Mathcad calculations have been compared with results given in the source.

Fig. 7. *Handbook of Civil Engineering Calculations*, p. 5.18, case 1.

Source book (pp. 457and 458):

General Plate Functions and Constants for Solid and Annular Circular Plates

$F_1 = \frac{1+\nu}{2}\frac{b}{r}\ln\frac{r}{b} + \frac{1-\nu}{4}\left(\frac{r}{b}-\frac{b}{r}\right)$

$C_1 = \frac{1+\nu}{2}\frac{b}{a}\ln\frac{a}{b} + \frac{1-\nu}{4}\left(\frac{a}{b}-\frac{b}{a}\right)$

$F_2 = \frac{1}{4}\left[1-\left(\frac{b}{r}\right)^2\left(1+2\ln\frac{r}{b}\right)\right]$

$C_2 = \frac{1}{4}\left[1-\left(\frac{b}{a}\right)^2\left(1+2\ln\frac{a}{b}\right)\right]$

$F_3 = \frac{b}{4r}\left\{\left[\left(\frac{b}{r}\right)^2+1\right]\ln\frac{r}{b}+\left(\frac{b}{r}\right)^2-1\right\}$

$C_3 = \frac{b}{4a}\left\{\left[\left(\frac{b}{a}\right)^2+1\right]\ln\frac{a}{b}+\left(\frac{b}{a}\right)^2-1\right\}$

$F_4 = \frac{1}{2}\left[(1+\nu)\frac{b}{r}+(1-\nu)\frac{r}{b}\right]$

$C_4 = \frac{1}{2}\left[(1+\nu)\frac{b}{a}+(1-\nu)\frac{a}{b}\right]$

$F_5 = \frac{1}{2}\left[1-\left(\frac{b}{r}\right)^2\right]$

$C_5 = \frac{1}{2}\left[1-\left(\frac{b}{a}\right)^2\right]$

$F_6 = \frac{b}{4r}\left[\left(\frac{b}{r}\right)^2-1+2\ln\frac{r}{b}\right]$

$C_6 = \frac{b}{4a}\left[\left(\frac{b}{a}\right)^2-1+2\ln\frac{a}{b}\right]$

$F_7 = \frac{1}{2}(1-\nu^2)\left(\frac{r}{b}-\frac{b}{r}\right)$

$C_7 = \frac{1}{2}(1-\nu^2)\left(\frac{a}{b}-\frac{b}{a}\right)$

$F_8 = \frac{1}{2}\left[1+\nu+(1-\nu)\left(\frac{b}{r}\right)^2\right]$

$C_8 = \frac{1}{2}\left[1+\nu+(1-\nu)\left(\frac{b}{a}\right)^2\right]$

$F_9 = \frac{b}{r}\left\{\frac{1+\nu}{2}\ln\frac{r}{b}+\frac{1-\nu}{4}\left[1-\left(\frac{b}{r}\right)^2\right]\right\}$

$C_9 = \frac{b}{a}\left\{\frac{1+\nu}{2}\ln\frac{a}{b}+\frac{1-\nu}{4}\left[1-\left(\frac{b}{a}\right)^2\right]\right\}$

TABLE 11.2 Formulas for flat circular plates of constant thickness (*Continued*)

$L_1 = \frac{1+\nu}{2}\frac{r_o}{a}\ln\frac{r_0}{a} + \frac{1-\nu}{4}\left(\frac{a}{r_o}-\frac{r_o}{a}\right)$

$G_1 = \left[\frac{1+\nu}{2}\frac{r_o}{r}\ln\frac{r}{r_0} + \frac{1-\nu}{4}\left(\frac{r}{r_o}-\frac{r_o}{r}\right)\right]\langle r-r_o\rangle^0$

$L_2 = \frac{1}{4}\left[1-\left(\frac{r_o}{a}\right)^2\left(1+2\ln\frac{a}{r_o}\right)\right]$

$G_2 = \frac{1}{4}\left[1-\left(\frac{r_o}{r}\right)^2\left(1+2\ln\frac{r}{r_o}\right)\right]\langle r-r_o\rangle^0$

$L_3 = \frac{r_o}{4a}\left\{\left[\left(\frac{r_o}{a}\right)^2+1\right]\ln\frac{a}{r_o}+\left(\frac{r_o}{a}\right)^2-1\right\}$

$G_3 = \frac{r_o}{4r}\left\{\left[\left(\frac{r_o}{r}\right)^2+1\right]\ln\frac{r}{r_o}+\left(\frac{r_o}{r}\right)^2-1\right\}\langle r-r_o\rangle^0$

$L_4 = \frac{1}{2}\left[(1+\nu)\frac{r_o}{a}+(1-\nu)\frac{a}{r_o}\right]$

$G_4 = \frac{1}{2}\left[(1+\nu)\frac{r_o}{r}+(1-\nu)\frac{r}{r_o}\right]\langle r-r_o\rangle^0$

$L_5 = \frac{1}{2}\left[1-\left(\frac{r_o}{a}\right)^2\right]$

$G_5 = \frac{1}{2}\left[1-\left(\frac{r_o}{r}\right)^2\right]\langle r-r_o\rangle^0$

$L_6 = \frac{r_o}{4a}\left[\left(\frac{r_o}{a}\right)^2-1+2\ln\frac{a}{r_o}\right]$

$G_6 = \frac{r_o}{4r}\left[\left(\frac{r_o}{r}\right)^2-1+2\ln\frac{r}{r_o}\right]\langle r-r_o\rangle^0$

$L_7 = \frac{1}{2}(1-\nu^2)\left(\frac{a}{r_o}-\frac{r_o}{a}\right)$

$G_7 = \frac{1}{2}(1-\nu^2)\left(\frac{r}{r_o}-\frac{r_o}{r}\right)\langle r-r_o\rangle^0$

$L_8 = \frac{1}{2}\left[1+\nu+(1-\nu)\left(\frac{r_o}{a}\right)^2\right]$

$G_8 = \frac{1}{2}\left[1+\nu+(1-\nu)\left(\frac{r_o}{r}\right)^2\right]\langle r-r_o\rangle^0$

$L_9 = \frac{r_o}{a}\left\{\frac{1+\nu}{2}\ln\frac{a}{r_o}+\frac{1-\nu}{4}\left[1-\left(\frac{r_o}{a}\right)^2\right]\right\}$

$G_9 = \frac{r_o}{r}\left\{\frac{1+\nu}{2}\ln\frac{r}{r_o}+\frac{1-\nu}{4}\left[1-\left(\frac{r_o}{r}\right)^2\right]\right\}\langle r-r_o\rangle^0$

Mathcad solution:

$$F_{plt}(r,b) \equiv \begin{bmatrix} \left(\frac{1+\nu}{2}\right)\cdot\left(\frac{b}{r}\right)\cdot\ln\left(\frac{r}{b}\right)+\left(\frac{1-\nu}{4}\right)\cdot\left(\frac{r}{b}-\frac{b}{r}\right) \\ \frac{1}{4}\cdot\left[1-\left(\frac{b}{r}\right)^2\cdot\left(1+2\cdot\ln\left(\frac{r}{b}\right)\right)\right] \\ \frac{b}{4\cdot r}\cdot\left[\left[\left(\frac{b}{r}\right)^2+1\right]\cdot\ln\left(\frac{r}{b}\right)+\left(\frac{b}{r}\right)^2-1\right] \\ \frac{1}{2}\cdot\left[(1+\nu)\cdot\frac{b}{r}+(1-\nu)\cdot\frac{r}{b}\right] \\ \frac{1}{2}\cdot\left[1-\left(\frac{b}{r}\right)^2\right] \\ \frac{b}{4\cdot r}\cdot\left[\left(\frac{b}{r}\right)^2-1+2\cdot\ln\left(\frac{r}{b}\right)\right] \\ \frac{1}{2}\cdot\left(1-\nu^2\right)\cdot\left(\frac{r}{b}-\frac{b}{r}\right) \\ \frac{1}{2}\cdot\left[1+\nu+(1-\nu)\cdot\left(\frac{b}{r}\right)^2\right] \\ \frac{b}{r}\cdot\left[\left(\frac{1+\nu}{2}\right)\cdot\ln\left(\frac{r}{b}\right)+\left(\frac{1-\nu}{4}\right)\cdot\left[1-\left(\frac{b}{r}\right)^2\right]\right] \end{bmatrix}$$

$F(r) \equiv F_{plt}(r,b)$

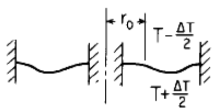
$C \equiv F(a)$

$G(r) \equiv F_{plt}(r,r_o)\cdot(r > r_o)$

$L \equiv G(a)$

Fig. 8. *Roark's Formulas for Stress and Strain*, Table 11.2, case 8h, p. 487. Calculations of general plate functions and constants.

Source book (p. 487):

8h. Outer edge fixed, inner edge fixed 	$y_b = 0, \quad \theta_b = 0, \quad y_a = 0, \quad \theta_a = 0$ $M_{rb} = \frac{-\gamma(1+\nu)\Delta T D}{t} \frac{C_6 L_2 - C_3 L_5}{C_2 C_6 - C_3 C_5}$ $Q_b = \frac{\gamma(1+\nu)\Delta T D}{at} \frac{C_5 L_2 - C_2 L_5}{C_2 C_6 - C_3 C_5}$ $M_{ra} = M_{rb} C_8 + Q_b a C_9 - \frac{\gamma(1+\nu)\Delta T D}{t}(1 - L_8)$ $Q_a = Q_b \frac{b}{a}$

Mathcad solution:

Plate constant: $D := E \cdot \frac{t^3}{12 \cdot (1 - \nu^2)}$

$D = 175.824 \cdot \text{kip} \cdot \text{in}$

Radial bending moment at inner edge: $M_{rb} := \frac{-\gamma \cdot (1+\nu) \cdot \Delta T \cdot D}{t} \cdot \left(\frac{C_6 \cdot L_2 - C_3 \cdot L_5}{C_2 \cdot C_6 - C_3 \cdot C_5} \right)$

$M_{rb} = 430.654 \cdot \frac{\text{lbf} \cdot \text{in}}{\text{in}}$

Unit shear force at inner edge: $Q_b := \frac{\gamma \cdot (1+\nu) \cdot \Delta T \cdot D}{a \cdot t} \cdot \left(\frac{C_5 \cdot L_2 - C_2 \cdot L_5}{C_2 \cdot C_6 - C_3 \cdot C_5} \right)$

$Q_b = -501.237 \cdot \frac{\text{lbf}}{\text{in}}$

Radial bending moment at outer edge: $M_{ra} := M_{rb} \cdot C_8 + Q_b \cdot a \cdot C_9 - \frac{\gamma \cdot (1+\nu) \cdot \Delta T \cdot D}{t} \cdot (1 - L_8)$

$M_{ra} = -1.0711 \cdot \frac{\text{kip} \cdot \text{in}}{\text{in}}$

Unit shear force at outer edge: $Q_a := Q_b \cdot \frac{b}{a}$

$Q_a = -350.866 \cdot \frac{\text{lbf}}{\text{in}}$

Fig. 9. *Roark's Formulas for Stress and Strain*, Table 11.2, case 8h, p. 487. Calculations of boundary conditions.

Source book (p. 484):

General expressions for deformations, moments, and shears:

$$y = y_b + \theta_b r F_1 + M_{rb}\frac{r^2}{D}F_2 + Q_b\frac{r^3}{D}F_3 + \frac{\gamma(1+\nu)\Delta T}{t}r^2 G_2$$

$$\theta = \theta_b F_4 + M_{rb}\frac{r}{D}F_5 + Q_b\frac{r^2}{D}F_6 + \frac{\gamma(1+\nu)\Delta T}{t}rG_5$$

$$M_r = \theta_b\frac{D}{r}F_7 + M_{rb}F_8 + Q_b rF_9 + \frac{\gamma(1+\nu)\Delta T}{t}D(G_8 - \langle r - r_o\rangle^0)$$

$$M_t = \frac{\theta D(1-\nu^2)}{r} + \nu M_r - \frac{\gamma(1-\nu^2)\Delta TD}{t}\langle r - r_o\rangle^0$$

$$Q = Q_b\frac{b}{r}$$

For the numerical data given below, $\nu = 0.3$

$$y = K_y\frac{\gamma\Delta Ta^2}{t}, \quad \theta = K_\theta\frac{\gamma\Delta Ta}{t}, \quad M = K_M\frac{\gamma\Delta TD}{t}, \quad Q = K_Q\frac{\gamma\Delta TD}{at}$$

Used in test procedure, see Fig. 14

Mathcad solution:

General expressions for deformation, moment, and shear given below can be found on p. 484:

Deformations at a radius r (deflection is positive upward)

$$y(r) := y_b + \theta_b \cdot r \cdot F(r)_1 + M_{rb}\cdot\frac{r^2}{D}\cdot F(r)_2 + Q_b\cdot\frac{r^3}{D}\cdot F(r)_3 + \frac{\gamma\cdot(1+\nu)\cdot\Delta T}{t}\cdot r^2\cdot G(r)_2$$

Radial slope of the plate (slope is positive when deflection y increases positively as r increas)

$$\theta(r) := \theta_b\cdot F(r)_4 + M_{rb}\cdot\frac{r}{D}\cdot F(r)_5 + Q_b\cdot\frac{r^2}{D}\cdot F(r)_6 + \frac{\gamma\cdot(1+\nu)\cdot\Delta T}{t}\cdot r\cdot G(r)_5$$

Unit radial bending moment (moment is positive when creating compression on the top surface)

$$M_r(r) := \theta_b\cdot\frac{D}{r}\cdot F(r)_7 + M_{rb}\cdot F(r)_8 + Q_b\cdot r\cdot F(r)_9 + \frac{\gamma\cdot(1+\nu)\cdot\Delta T}{t}\cdot D\cdot\left[G(r)_8 - (r > r_o)\right]$$

Unit tangential bending moment (moment is positive when creating compression on the top surface)

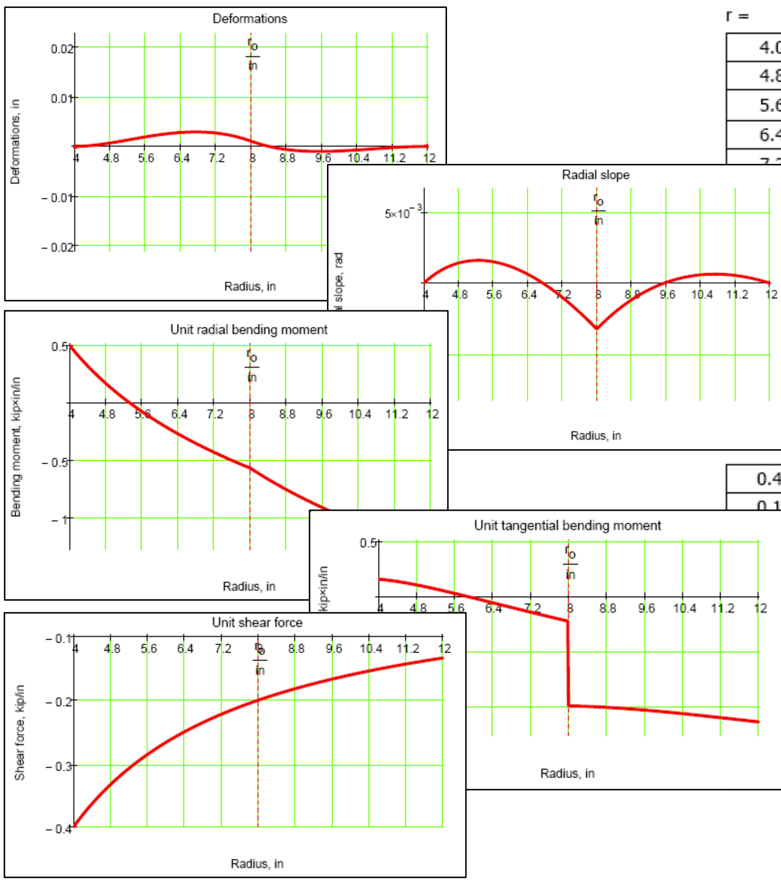
$$M_t(r) := \frac{\theta(r)\cdot D\cdot(1-\nu^2)}{r} + \nu\cdot M_r(r) - \frac{\gamma\cdot(1-\nu^2)\cdot\Delta T\cdot D}{t}\cdot(r > r_o)$$

Unit shear force (shear is positive when acting upward on the inner edge of a given annular section)

$$Q(r) := Q_b\cdot\frac{b}{r}$$

Fig. 10. *Roark's Formulas for Stress and Strain*, Table 11.2, case 8h, p. 487. Calculations of deflection, slope, moments and shear forces.

Graphics



Tables

r = (·in)	y(r) = (·in)	θ(r) = (·rad)
4.000	0.000	0.000
4.800	$6.635 \cdot 10^{-4}$	$1.400 \cdot 10^{-3}$
5.600	$1.894 \cdot 10^{-3}$	$1.493 \cdot 10^{-3}$
6.400	$2.798 \cdot 10^{-3}$	$6.289 \cdot 10^{-4}$
7.[illegible]00	$2.702 \cdot 10^{-3}$	$-9.819 \cdot 10^{-4}$
[illegible]00	$1.065 \cdot 10^{-3}$	$-3.201 \cdot 10^{-3}$
[illegible]00	$-6.216 \cdot 10^{-4}$	$-1.167 \cdot 10^{-3}$
[illegible]00	$-1.021 \cdot 10^{-3}$	$4.603 \cdot 10^{-5}$
[illegible]00	$-7.288 \cdot 10^{-4}$	$5.799 \cdot 10^{-4}$
[illegible]00	$-2.461 \cdot 10^{-4}$	$5.382 \cdot 10^{-4}$
[illegible]00	0.000	0.000

[illegible] (·kip·in/in)	$M_t(r)$ = (·kip·in/in)	Q(r) = (·kip/in)
0.4902	0.1471	-0.3994
0.1630	0.0956	-0.3329
[illegible]803	0.0186	-0.2853
[illegible]729	-0.0661	-0.2497
[illegible]322	-0.1515	-0.2219
[illegible]681	-1.0025	-0.1997
[illegible]533	-1.0152	-0.1816
[illegible]092	-1.0400	-0.1664
[illegible]434	-1.0721	-0.1536
[illegible]609	-1.1086	-0.1427
[illegible]652	-1.1476	-0.1331

Fig. 11. *Roark's Formulas for Stress and Strain*, Table 11.2, case 8h, p. 487. Output of results in graphic and tabular formats (missing in the source but very useful for validation).

Source book (p. 457):

General Plate Functions and Constants

$$F_1 = \frac{1+\nu a}{2}\frac{b}{r}\ln\frac{r}{b} + \frac{1-\nu}{4}\left(\frac{r}{b}-\frac{b}{r}\right)$$

$$F_2 = \frac{1}{4}\left[1-\left(\frac{b}{r}\right)^2\left(1+2\ln\frac{r}{b}\right)\right]$$

Misprint

Mathcad solution:

$$\left(\frac{1+\nu}{2}\right)\cdot\left(\frac{b}{r}\right)\cdot\ln\left(\frac{r}{b}\right)+\left(\frac{1-\nu}{4}\right)\cdot\left(\frac{r}{b}-\frac{b}{r}\right)$$

Fixed

Fig. 12. *Roark's Formulas for Stress and Strain*, Table 11.2, case 8h, p. 487. Misprint is found as a result of validation of equation and units.

Source book, Table 11.1 (page 455):

TABLE 11.1 Numerical values for functions used in Table 11.2 (*Continued*)

r_o/r	0.400	$\frac{1}{3}$	0.300	0.250	0.200
G_1	0.605736	0.704699	0.765608	0.881523	1.049227
G_2	0.136697	0.161188	0.173321	0.191053	0.207811
G_3	0.022290	0.027649	0.030175	0.033465	0.035691
G_4	1.135000	1.266667	1.361667	1.562500	1.880000
G_5	0.420000	0.444444	0.455000	0.468750	0.480000
G_6	0.099258	0.109028	0.112346	0.114693	0.112944
G_7	0.955500	1.213333	1.380167	1.706250	2.184000
G_8	0.706000	0.688889	0.681500	0.671875	0.664000
G_9	0.297036		0.282550	0.266288	0.242827
G_{11}	0.003833	0.005499	0.006463	0.008057	0.009792
G_{12}	0.000827	0.001208	0.001435	0.001822	0.002266
G_{13}	0.000289	0.000427	0.000510	0.000654	0.000822
G_{14}	0.024248	0.031211	0.034904	0.040595	0.046306
G_{15}	0.006691	0.008790	0.009945	0.011798	0.013777
G_{16}	0.002840	0.003770	0.004290	0.005138	0.006065
G_{17}	0.119723	0.139340	0.148888	0.162637	0.175397
G_{18}	0.044939	0.053402	0.057723	0.064263	0.070816
G_{19}	0.023971	0.028769	0.031261	0.035098	0.039031

Result

Mathcad solution:

For QC only

Result

$$F_{plt}(12in, 4.8in) = \begin{pmatrix} 0.605736 \\ 0.136697 \\ 0.022290 \\ 1.135000 \\ 0.420000 \\ 0.099258 \\ 0.955500 \\ 0.706000 \\ 0.297036 \end{pmatrix}$$

Result

$$G\left(\frac{r_o}{0.4}\right) = \begin{pmatrix} 0.605736 \\ 0.136697 \\ 0.022290 \\ 1.135000 \\ 0.420000 \\ 0.099258 \\ 0.955500 \\ 0.706000 \\ 0.297036 \end{pmatrix}$$

Fig. 13. *Roark's Formulas for Stress and Strain*, Table 11.2, case 8h, p. 487. Validation of general plate functions and constants using Table 11.1, p. 455.

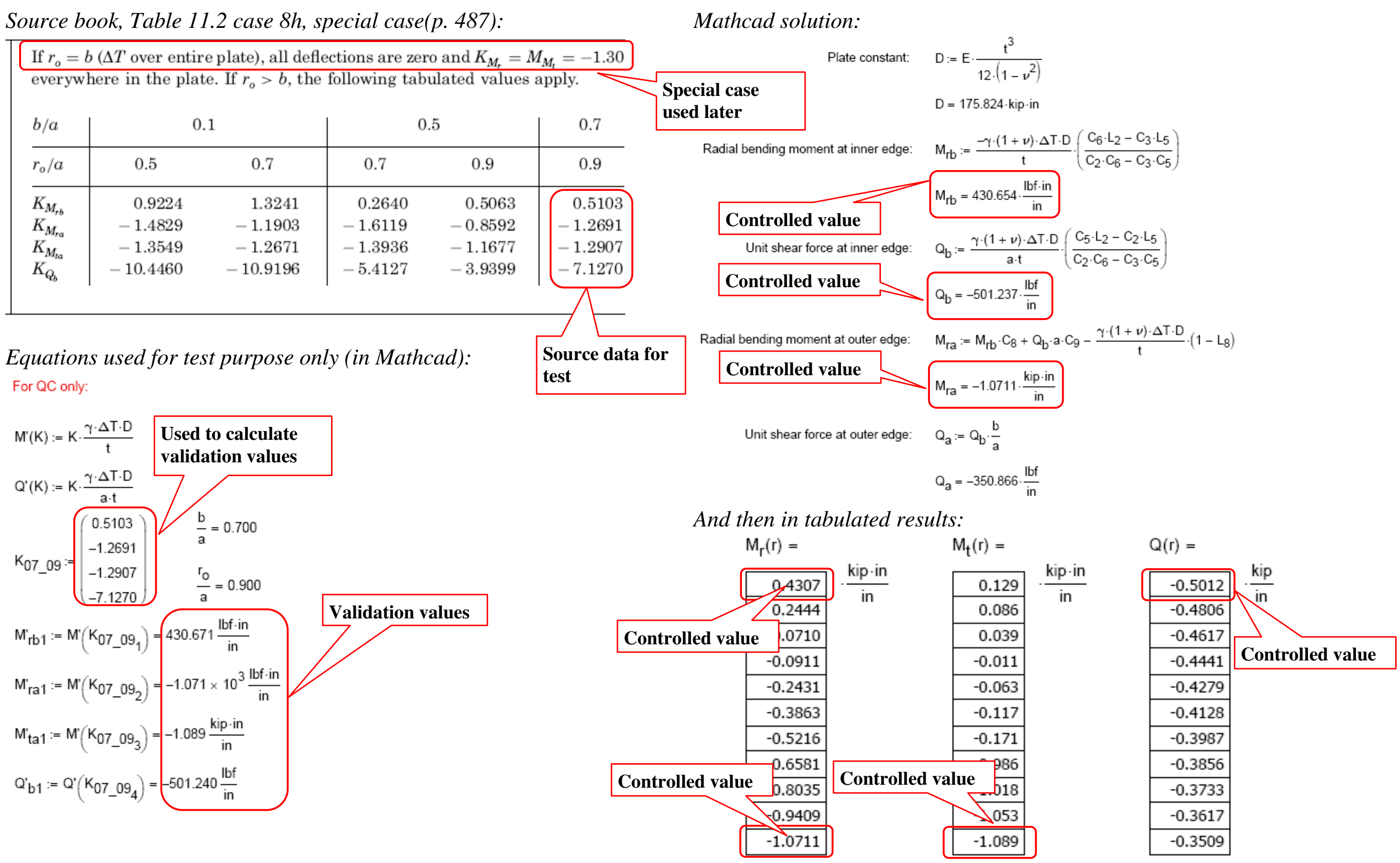
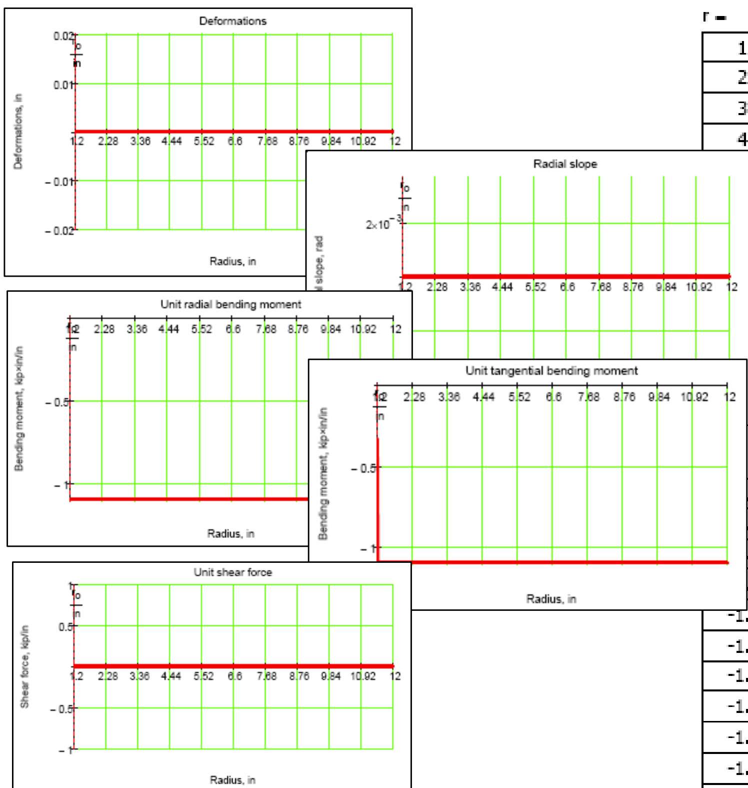


Fig. 14. *Roark's Formulas for Stress and Strain*, Table 11.2, case 8h, p. 487. Boundary moments and shear values are validated by results obtained from equations on p. 484 (*see* ***Fig. 10***) using coefficients determined for special cases.

Graphics



Tables

r = (·in)	y(r) = (·in)	θ(r) = (·rad)
1.200	0.000	0.000
2.280	0.000	0.000
3.360	0.000	0.000
4.440	0.000	0.000
.520	0.000	0.000
.600	0.000	0.000
.680	0.000	0.000
.760	0.000	0.000
.840	0.000	0.000
.920	0.000	0.000
.000	0.000	0.000

= (·kip·in/in)	$M_t(r)$ = (·kip·in/in)	Q(r) = (·kip/in)
.0971	-0.329	0.0000
.0971	-1.097	0.0000
.0971	-1.097	0.0000
.0971	-1.097	0.0000
-1.0971	-1.097	0.0000
-1.0971	-1.097	0.0000
-1.0971	-1.097	0.0000
-1.0971	-1.097	0.0000
-1.0971	-1.097	0.0000
-1.0971	-1.097	0.0000
-1.0971	-1.097	0.0000

Fig. 15. *Roark's Formulas for Stress and Strain*, Table 11.2, case 8h, p. 487. Special case at $r_0=b$ for this example is described on p. 487 (see ***Fig. 14***).

Mathcad solution calculated at $r_0=b$

r = (in)	y(r) = (in)	θ(r) = (rad)
1.200	0.000	0.000
2.280	0.000	0.000
3.360	0.000	0.000
4.440	0.000	0.000
5.520	0.000	0.000
6.600	0.000	0.000
7.680	0.000	0.000
8.760	0.000	0.000
9.840	0.000	0.000
10.920	0.000	0.000
12.000	0.000	0.000

$M_r(r)$ = (kip·in/in)	$M_t(r)$ = (kip·in/in)	Q(r) = (kip/in)
-1.0971	-0.329	0.0000
-1.0971	-1.097	0.0000
-1.0971	-1.097	0.0000
-1.0971	-1.097	0.0000
-1.0971	-1.097	0.0000
-1.0971	-1.097	0.0000
-1.0971	-1.097	0.0000
-1.0971	-1.097	0.0000
-1.0971	-1.097	0.0000
-1.0971	-1.097	0.0000
-1.0971	-1.097	0.0000

Mathsoft solution calculated at $r_0=b$

$n := 10$

$\Delta r := \frac{a-b}{n} = 1.08 \cdot in$

$r := b, b+\Delta r .. a$

r = (in)	y(r, 3) = (in)	θ(r, 3) = (rad)
1.2	0	0
2.28	0	0
3.36	0	0
4.44	0	0
5.52	0	0
6.6	0	0
7.68	0	0
8.76	0	0
9.84	0	0
10.92	0	0
12	0	0

$M_r(r,3)$ = (kip·in/in)	$M_t(r,3)$ = (kip·in/in)	Q(r, 3) = (kip/in)
−1.097	−0.329	0
−1.097	−1.097	0
−1.097	−1.097	0
−1.097	−1.097	0
−1.097	−1.097	0
−1.097	−1.097	0
−1.097	−1.097	0
−1.097	−1.097	0
−1.097	−1.097	0
−1.097	−1.097	0
−1.097	−1.097	0

Fig. 16. *Roark's Formulas for Stress and Strain*, Table 11.2, case 8h, p. 487. Special case validation using Mathsoft solution.

Mathcad solution using random input values

r = (·in)	y(r) = (·in)	θ(r) = (·rad)
4.000	0.000	0.000
4.800	$6.635\cdot10^{-4}$	$1.400\cdot10^{-3}$
5.600	$1.894\cdot10^{-3}$	$1.493\cdot10^{-3}$
6.400	$2.798\cdot10^{-3}$	$6.289\cdot10^{-4}$
7.200	$2.702\cdot10^{-3}$	$-9.819\cdot10^{-4}$
8.000	$1.065\cdot10^{-3}$	$-3.201\cdot10^{-3}$
8.800	$-6.216\cdot10^{-4}$	$-1.167\cdot10^{-3}$
9.600	$-1.021\cdot10^{-3}$	$4.603\cdot10^{-5}$
10.400	$-7.288\cdot10^{-4}$	$5.799\cdot10^{-4}$
11.200	$-2.461\cdot10^{-4}$	$5.382\cdot10^{-4}$
12.000	0.000	0.000

$M_r(r)$ = ($\cdot\frac{kip\cdot in}{in}$)	$M_t(r)$ = ($\cdot\frac{kip\cdot in}{in}$)	Q(r) = ($\cdot\frac{kip}{in}$)
0.4902	0.1471	-0.3994
0.1630	0.0956	-0.3329
-0.0803	0.0186	-0.2853
-0.2729	-0.0661	-0.2497
-0.4322	-0.1515	-0.2219
-0.5681	-1.0025	-0.1997
-0.7533	-1.0152	-0.1816
-0.9092	-1.0400	-0.1664
-1.0434	-1.0721	-0.1536
-1.1609	-1.1086	-0.1427
-1.2652	-1.1476	-0.1331

Mathsoft solution calculated using the same input values

$n := 10$

$\Delta r := \frac{a-b}{n} = 0.80\cdot in$

$r := b, b + \Delta r .. a$

$$r = \begin{pmatrix} 4 \\ 4.8 \\ 5.6 \\ 6.4 \\ 7.2 \\ 8 \\ 8.8 \\ 9.6 \\ 10.4 \\ 11.2 \\ 12 \end{pmatrix}\cdot in \quad y(r,3) = \begin{pmatrix} 0 \\ 6.635\times10^{-4} \\ 0.002 \\ 0.003 \\ 0.003 \\ 0.001 \\ -6.216\times10^{-4} \\ -0.001 \\ -7.288\times10^{-4} \\ -2.461\times10^{-4} \\ 0 \end{pmatrix}\cdot in \quad \theta(r,3) = \begin{pmatrix} 0 \\ 0.001 \\ 0.001 \\ 6.289\times10^{-4} \\ -9.819\times10^{-4} \\ -0.003 \\ -0.001 \\ 4.603\times10^{-5} \\ 5.799\times10^{-4} \\ 5.382\times10^{-4} \\ 0 \end{pmatrix}\cdot rad$$

$$M_r(r,3) = \begin{pmatrix} 0.49 \\ 0.163 \\ -0.08 \\ -0.273 \\ -0.432 \\ -0.568 \\ -0.753 \\ -0.909 \\ -1.043 \\ -1.161 \\ -1.265 \end{pmatrix}\cdot\frac{kip\cdot in}{in} \quad M_t(r,3) = \begin{pmatrix} 0.147 \\ 0.096 \\ 0.019 \\ -0.066 \\ -0.151 \\ -1.002 \\ -1.015 \\ -1.04 \\ -1.072 \\ -1.109 \\ -1.148 \end{pmatrix}\cdot\frac{kip\cdot in}{in} \quad Q(r,3) = \begin{pmatrix} -0.399 \\ -0.333 \\ -0.285 \\ -0.25 \\ -0.222 \\ -0.2 \\ -0.182 \\ -0.166 \\ -0.154 \\ -0.143 \\ -0.133 \end{pmatrix}\cdot\frac{kip}{in}$$

Fig. 17. *Roark's Formulas for Stress and Strain*, Table 11.2, case 8h, p. 487. Validation using Mathsoft solution and random variables.

Appendix

Best Practices

General Comments

- Begin your Mathcad documents using the supplied Mathcad template for the specific book you are working on, or from a Mathcad file you already wrote that used this template. It is important for consistency that you utilize this template as it contains several non-default settings.

- Turn ON all redefinition warnings (Tools > Preferences > Warnings) to ensure NO (or minimal) green squiggly lines show up in the documents you make. If you get any, do your best to rename variables to avoid this.

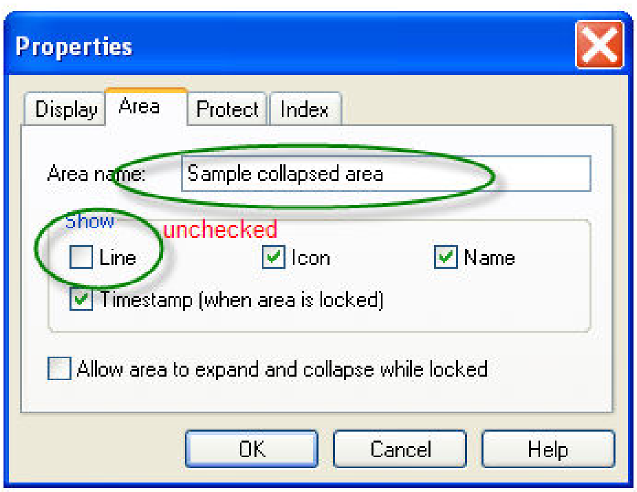
- In general choose highlighting over bordering of entities because region borders in Mathcad are too tight.

F = 29.973·ksi   F = 29.973·ksi   In the image with the border, it is difficult to see the "i" in ksi.

- View your documents with various screen resolutions to ensure the document looks good and regions do not wrap funny or overlap.

- Page breaks - when needed, place manual page breaks in document as needed to get good visual output. Print document or view as PDF to ensure page formatting and page breaks look acceptable.

- Use collapsed areas (Mathcad menu, Insert > Area) to place extra calculations that were needed. When you generate these collapsed areas, place a page break at the top (inside) of the collapsed area and at the bottom (inside) of the collapsed area. After creating the area, right click, select properties and specify on the Area tab an area name and unselect the Line option. Below is an example.



Working with Text Regions

- Align text regions to obtain a uniform look when possible.
- Do NOT include math regions within text regions. While Mathcad currently supports this, future versions are likely to NOT support this.
- Ensure that text regions and math regions are sufficiently spaced so that they do not overcrowded each other. Remember that the size of math regions can change for variables when the user enters different values.

$x := 3.429 \cdot ksi$

$x = 3.429 \cdot ksi$ $\qquad$ $x = 3.429 \times 10^3 \cdot psi$ $\qquad$ Notice the size difference.

- Always manually stretch text regions slightly to avoid unintended text region wrapping when the user switches to different screen resolutions or zooms within Mathcad. This needs to be tested by the user for their documents. This is a long-standing issue with Mathcad that will not be fixed until Spirit is released (the next generation of Mathcad product).
- Do NOT use Tabs (the Tab key) in text regions. There is a know bug with Tabs that causes formatting to sometimes get distorted. Instead use the Mathcad menu "Format > Paragraph, Left Indent" to create indents or place the regions where desired and use the alignment menu icons of Mathcad to align regions vertically or horizontally.

Working with Math Regions

- Using the supplied templates, the worksheet variable ORIGIN will be 1. Do NOT change this.
- When entering equations, always explicitly type multiplication so that the dot shows. When evaluating results, right click on the units place holder and select "View Multiplication As: Narrow dot".

these are preferred $\qquad$ $r := 22 \cdot in$ $\qquad$ $Area := 2 \cdot \pi \cdot 22 \cdot r^2$ $\qquad$ $Area = 43.163 \cdot m^2$

these are NOT preferred $\qquad$ $y := 22in$ $\qquad$ $Areay := 2\pi\, y^2$ $\qquad$ $Areay = 1.962 \cdot m^2$

In a nut shell, multiplication should be shown just like +, -, and /. When one chooses not to show multiplication, then unclear results can occur as shown below

Is the entity to the right millimeters or meter times meter? $\qquad$ $Areay = 1.962\, m \cdot m$

- Always place a units in the units place holder when evaluating a result that has units. We need to do this because trailing zeros is enabled in our templates and this causes the undesirable result as seen below.

$Areay = 1.962\, m^{2.000}$ $\qquad$ the zeros in the power is not desired. Also, no multiplication symbol appears.

$Areay = 1.962 \cdot m^2$ $\qquad$ Manual entry of m^2 in the units place holder along with "View Multiplication As: Narrow dot" yields this preferred result.

- Do NOT use the global equals sign ≡ in equation definitions. Always use the local definition approach (:=). Global definitions can become too confusing to the use.

- Do NOT use the "View Definition As" feature to change the := to just an = sign. This again will make the document confusing to the user.

- Avoid using in-line equation defintion and evaluation. There is a known bug that causes the results to not update sometimes. This but does not occur on all computers or set-ups and is a bit random. So for robustness, use a separate defintion and evalution as shown below.

$a := 3 \cdot in$ $b := 4 \cdot in$

Do NOT do this $X := a + b = 7.000 \cdot in$

Instead do this $Y := a + b$

$Y = 7.000 \cdot in$

Also note that it is safer to evaluate Y below its defnition that next to it. See below for two examples of problems that can occur if the user slightly modifies the position of things.

$Z := a + b$ $Z = \blacksquare \cdot in$ <= This gives an error

$Y := a + 3 \cdot b$ $Y = 7.000 \cdot in$ This gives the WRONG answer

$Y = 15.000 \cdot in$ This gives the correct answer

- Do NOT use the global equals sign ≡ in equation definitions. Always use the local definition approach (:=). Global definitions can become too confusing to the use.

- Do NOT use the "View Definition As" feature to change the := to just an = sign. This again will make the document confusing to the user.

- Avoid using in-line equation defintion and evaluation. There is a known bug that causes the results to not update sometimes. This but does not occur on all computers or set-ups and is a bit random. So for robustness, use a separate defintion and evalution as shown below.

$a := 3 \cdot in$ $b := 4 \cdot in$

Do NOT do this $X := a + b = 7.000 \cdot in$

Instead do this $Y := a + b$

$Y = 7.000 \cdot in$

Also note that it is safer to evaluate Y below its defnition that next to it. See below for two examples of problems that can occur if the user slightly modifies the position of things.

$Z := a + b$ $Z = \blacksquare \cdot in$ <= This gives an error

$Y := a + 3 \cdot b$ $Y = 7.000 \cdot in$ This gives the WRONG answer

$Y = 15.000 \cdot in$ This gives the correct answer