



Finite Element Structural Analysis on an Excel Spreadsheet

An Online Continuing Education Course for Engineers

Course Number: S-4005

Credit: 4 Hours / 4 PDH / 4 CPD

Finite Element Structural Analysis on an Excel Spreadsheet

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COURSE DESCRIPTION:

Conventional thinking is that Finite Element (FE) analysis is complex and requires expensive commercial software. This course shows that this is not necessarily true; FE theory can be understood in a few hours and is simple enough to put on an Excel spreadsheet. Finite Element software is an essential tool for structural engineers, but it need not be complex or expensive. This course will present finite elements in a simplified spreadsheet form, combining the power of the FE method with the versatility of a spreadsheet format.

The user is provided with a Microsoft Excel spreadsheet that solves FE two-dimensional (2D) frame-type structural engineering problems. This spreadsheet is simplistic in comparison to commercial software and much more limited in capabilities, but it is completely adequate for many structural building frame-type problems. I have used the FE spreadsheet for years, and it has been invaluable. It is easy to learn if the user is already familiar with spreadsheets, and it is much less expensive than commercial FE software.

Conventional FE thinking	Spreadsheet-based FE thinking
Huge amounts of data & equations	Data, equations, results on one spreadsheet
Complex "black box" algorithms	Formulas are all on one spreadsheet
Complex theory, beyond the average user	Calculation steps and intermediate calculation results all on one spreadsheet
Commercial software is best for handling complex algorithms and complex theory	Spreadsheets are best for handling huge amounts of data and equations
Commercial software is expensive but needed.	The FE spreadsheet is free, and most engineers already have the software necessary for spreadsheets.

This course is divided into a number of sections, covering:

- Introduction to FE
- Definitions and terminology
- Finite Element examples / applications
- Finite element theory
- Capabilities and limitations of the FE spreadsheet
- Summary

COURSE OUTLINE:

The course introduction provides a description of finite element analysis, as well as some of the typical assumptions underlying structural finite element analysis.

The first portion of the course provides definitions and terminology as they apply to this course. Finite element analysis has broad application, and in different contexts, terms may have different meanings, so this section defines terms as used in this course.

The second portion of the course provides a number of FE analysis examples/applications for structural engineers. It is important to see applications and results before delving into the theory, so the purpose of the analysis is clear, much as it is easier to bake cookies if you are allowed to sample a few before delving into the recipe.

The third portion of the course presents some methods to check results. The complexity of many FE problems makes checking a formidable task. Too often, engineers are enamored by the precision of computer-generated results, and they forget that accuracy is far more important. Checking is about verifying the accuracy, not precision.

FE method is, by nature, an approximate solution technique. The fourth portion of the course presents the capabilities and limitations of the FE spreadsheet provided with the course. All FE methods will have their strengths and weaknesses, their capabilities, and limitations. This section illustrates that point

with respect to the provided FE spreadsheet, with the idea that the engineer needs to be aware of similar boundaries for whatever method/software they are using.

LEARNING OBJECTIVES. After taking this course, the student will:

1. know the difference between truss, beam, and frame-type members
2. be able to differentiate node data from member data
3. know the difference between local coordinates & global coordinates
4. know some methods to check calculated computer results
5. understand continuous versus discretized systems
6. know the basic assumptions underlying FE theory
7. know some methods to simplify complex FE problems
8. have a basic understanding of the theory used to solve a FE problem
9. understand the transformation of local stiffness values to global stiffness values
10. be able to provide sufficient boundary conditions (supports) for stability
11. understand Microsoft Excel matrix size limitations and the corresponding FE spreadsheet problem-size limitations.
12. know the benefits, uses, and limitations of the provided FE spreadsheet

INTENDED AUDIENCE AND ASSUMED KNOWLEDGE

A typical user would be a structural design engineer working with a beam, truss, frame, or elastic foundation problems. The user should:

- have Excel 5.0 or higher software.
- have a working understanding of spreadsheet formulas (Visual Basic [VBA] programming and macro skills are not necessary).
- be able to create a structural 2D frame model with nodes and members.
- be aware of matrix mathematics (addition, multiplication, and inversion of matrices), although detailed knowledge of matrices is not needed.

BENEFIT TO THE AUDIENCE

This course presents Finite Element in an easy-to-learn format via a FE spreadsheet for Microsoft Excel. All of the intermediate steps and intermediate calculated values, for example, FE problems, are easily viewable on the spreadsheet. Understanding FE theory allows the user to, in many cases, forego commercial software and use more basic software, such as the FE spreadsheet. In addition to providing FE theory, this course provides a functional FE spreadsheet that is versatile, easy to use, and easy to understand. It can be used on any computer that has Microsoft Excel; no license or password, or hardware key is required. The spreadsheet can easily be customized by the user. It can be expanded or modified for specialized problems. It can be adapted from the structural discipline to other disciplines. It can be shared with others at no cost.

INTRODUCTION

Finite Element (FE) software is an essential tool for most structural design engineers, and at the cost of most commercial FE software, it had better be essential. The commercial FE software used by many engineering firms will provide you with more computer output than you could read in a month and more than you can understand in a year. Commercial programs are great for impressing clients and great for performing extensive analysis when really needed. But in the design of frame-type structures, rarely is all that power and output really needed.

In 25 years of engineering, I have never seen a design that was flawed because the designer failed to generate enough computer output. I have never seen a structure that was inadequate because the designer didn't use enough nodes in his analysis model. I have never seen an analysis that was erroneous because there weren't enough digits to the right of the decimal point. For most frame-type structure problems, the use of commercial FE software results in too much output, too many nodes, and too many insignificant digits.

In 10 years of private practice, I have relied almost exclusively on a FE spreadsheet for analyzing frame-type structures. I am presenting that spreadsheet in this course as a practical and effective design tool. Even if you need commercial FE software size and power for some problems, you will probably find the

FE spreadsheet to be superior for problems within its range. It is limited to 2-dimensional frames of about 50 nodes, but if your problem is within that range, you will find it is easier to use, easier to understand, easier to port, easier to check, and much less expensive than commercial programs.

FE method is a numerical solution technique used to analyze continuous systems in which the system is discretized into a finite number of elements. The continuity of the system is modeled by compatibility equations between adjacent elements. This course will focus on frame-type structures in which the elements are the framing members, and the compatibility is of force and deflection.

If we limit our scope to a single member, we can write the following:

- stress is linearly distributed
- elements are linear

proportional to member length
equation $\mathbf{f} = \mathbf{k} * \mathbf{d}$
of the member.

$\mathbf{f} = \mathbf{k} * \mathbf{d}$ is to structural analysis and, once solved, keep things simple).

In this course, you will learn to solve $\mathbf{F} = \mathbf{K} * \mathbf{D}$ for a system of members. You will learn to solve for \mathbf{f} , \mathbf{d} , and \mathbf{D} . And you will be able to see the benefits of keeping problems simple.

It should be emphasized that this course focuses on FE analysis of 2D structural frames subject to static loading, with all elements being linear members with nodes at each end. This is a very specific segment of a huge field of FE applications. FE analysis for this specific segment of problems is really an application of matrix mathematics to solve a series of simultaneous compatibility equations. Some would argue that this is not a true FE analysis since *the system itself is discretized* (a finite number of members connected at a finite number of joints, with closed-form solution shape functions).

To view the remainder of the course material and to take the quiz for PDH credit, you must purchase the course.

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