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**The Calculation Pad for
the Professional Engineer**



Eurocodes –

an opportunity to review your spreadsheets?

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Eurocodes – an opportunity to review your spreadsheets?

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Introduction

The introduction of the Eurocodes represents one of the largest challenges that the UK Structural Engineering industry is ever likely to experience. This period of significant change provides an unprecedented opportunity to review and improve on practices currently used within organisations. One such practice that has developed over the years, almost without planning, is the proliferation of spreadsheets used in design.

Spreadsheets typically represent small scale internal development undertaken by an individual and born from the desire to improve efficiency. Created on a very ad-hoc basis with little or no planning from higher management, spreadsheets tend to start as small "scratchpad" applications that often develop into much larger design tools over time.

When implemented and used correctly the spreadsheet is undoubtedly a powerful tool, however research by Professor Ray Panko of the University of Hawaii, based on field audits by organisations such as KPMG and Coopers and Lybrand, showed that of the 88 spreadsheets audited in 7 studies between 1995 and 2005, 94% contained errors⁽¹⁾.

As the Eurocodes start to be used, Engineers will require new electronic calculations to assist them with their designs. **Will Engineers start all over again writing new spreadsheets using the same unmanaged process or will management take the opportunity to review what they have and to introduce a more structured approach to small scale internal development?**

The Problem with Spreadsheets

Spreadsheet software is available to every Engineer, for this reason it is often the first tool an Engineer will use to assist with hand calculations, however this does not necessarily make it the right tool.

Footnotes

(1) *What We Know About Spreadsheet Errors, Raymond R. Panko, January 2005*

Quality Assurance

The ease with which even an inexperienced user can enter data and calculations into a spreadsheet and very quickly produce results can lead to the belief that spreadsheets are inherently easy to write and use. However as the requirements of a spreadsheet increase then its complexity does too. Completed spreadsheets often include many pages containing hundreds or even thousands of calculations. The problem with spreadsheets is that all those calculations are hidden in the formulae and cross references within the cells of the spreadsheet. Whilst it is possible to examine the formula in each cell one at a time, understanding how an entire spreadsheet works is often a monumental task. This makes full quality assurance very difficult to achieve.

| Total Beam Reactions | | | | | | | | | | | |
|--------------------------|--------------|---------|----------|----------|------------|----------|----------|----------|----------|----------|----------|
| Span | 1 | 2 | 3 | 4 | | | | | | | |
| Coord X | 0 | 0 | 0 | 0 | | | | | | | |
| Coord Y | 4 | 8 | 8 | 4 | | | | | | | |
| Coord Z | 0 | 0 | 0 | 0 | | | | | | 3 | |
| True Length | 4 | 8 | 8 | 4 | Beam | 24 | | | | 8.544004 | |
| Force Z | Projected XY | 4 | 8 | 8 | 4 | | | | | 8 | |
| Force Y | Projected XZ | 0 | 0 | 0 | 0 | | | | | 3 | |
| Force X | Projected YZ | 4 | 8 | 8 | 4 | | | | | 8.544004 | |
| Angle to Horizontal Plan | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | | | | | 20.5560 | |
| Angle to YZ Plane | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | | | | | 0.0000 | |
| Angle to XZ Plane | | 90.0000 | 90.0000 | 90.0000 | 90.0000 | | | | | 90.0000 | |
| Beam Loads | | | | | | | | | | | |
| | Value 1 | Value 2 | Length 1 | Length 2 | Angle | 0 | 0 | 0 | 0 | 0 | |
| | | | start | end | Total | Net Load | Net Load | Net Load | Net Load | Net Load | |
| Full UDL | 10 | | | | 40 | 80 | 80 | 40 | 240 | 85.44004 | |
| UDL | 9 | | 1.5 | 2.5 | 9 | 9 | 9 | 9 | 36 | 9 | |
| Point 1 | 3 | | start | | 3 | 3 | 3 | 3 | 12 | 3 | |
| Point 2 | 4 | | 3 | | 4 | 4 | 4 | 4 | 16 | 4 | |
| Point 3 | 5 | | end | | 5 | 5 | 5 | 5 | 20 | 5 | |
| Moment 1 | 0 | | start | | 0 | 0 | 0 | 0 | 0 | 0 | |
| Moment 2 | 0 | | 5 | | 0 | 0 | 0 | 0 | 0 | 0 | |
| Moment 3 | 0 | | end | | 0 | 0 | 0 | 0 | 0 | 0 | |
| VDL | 6 | 7 | 2 | 3 | 6.5 | 6.5 | 6.5 | 6.5 | 26 | 6.5 | |
| Trap | 8 | | 1 | | 24 | 56 | 56 | 24 | 160 | 60.35203 | |
| Total Local Reaction | | | | | | 91.5 | 163.5 | 163.5 | 91.5 | 510 | 173.2921 |
| Total Global Reaction | | | | | | 91.5 | 163.5 | 163.5 | 91.5 | | 163.5 |
| Global Z | | | | | Reaction X | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| | | | | | Reaction Y | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| | | | | | Reaction Z | 91.5000 | 163.5000 | 163.5000 | 91.5000 | 0.0000 | 163.5000 |
| Local z | | | | | Reaction X | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| | | | | | Reaction Y | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 60.8469 |
| | | | | | Reaction Z | 91.5000 | 163.5000 | 163.5000 | 91.5000 | 510.0000 | 162.2584 |
| Local y | | | | | Reaction X | 91.5000 | 163.5000 | 163.5000 | 91.5000 | 510.0000 | 173.2921 |

Figure 1: A Quality Assured Spreadsheet?

In theory the wide availability of spreadsheet software should allow spreadsheets to be shared easily; however in practice spreadsheets often prove to be difficult to use by anyone other than the original author. They tend to follow an individual's own stylistic way of working and often require a detailed understanding of the implementation for effective use. Even if a spreadsheet can be used by somebody else, what confidence can that person have that the spreadsheet actually works as intended and produces correct results?

The ability to quality assure electronic calculations is essential for use within a design environment.

Spreading Knowledge

Within a typical Engineering Practice it is very likely that nobody will be aware of all the spreadsheet development that has taken place. Very capable spreadsheets may have been written by different members of staff for their own personal use. This raises a number of issues, not least the availability of those spreadsheets to others. It would seem reasonable that if someone has written a useful spreadsheet that there are likely to be others within the same organization who would benefit from it too. However as stated previously spreadsheets are often difficult to use by anybody other than the original author.

Once an electronic calculation is developed by someone in an organisation, it should have the capability to be shared widely.

A Possible Alternative to the Spreadsheet

What is required is a platform that can be used to create calculations in a standard way, which can be easily used, verified and shared with others.

TEDDS[®] allows an Engineer to write calculations using Microsoft Word™ in much the same way as they might be written by hand. The important distinction between using Word and a spreadsheet to write calculations is that all calculations are clearly visible on the page. TEDDS[®] calculations are not a 'black box' solution. The calculations and the resulting output are intrinsically one and the same thing; there is no concept of using one process to calculate the required results and then using a different process to produce a report to present those results. A TEDDS[®] calculation is both the calculation and

the output in one single entity. This ensures that calculation can be easily followed resulting in easy checking and verification. Clearly CSC (UK) Ltd has adopted this technology in the commercially available library of TEDDS® calculations.

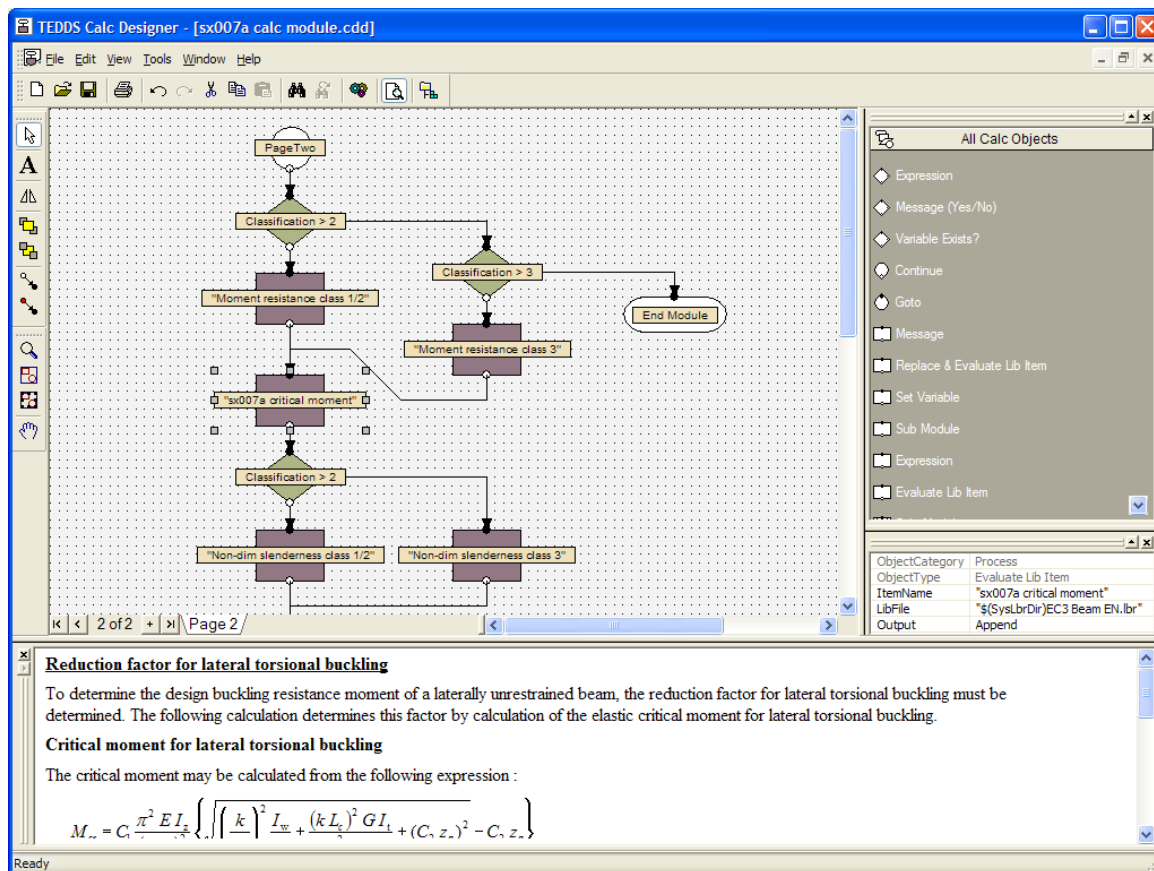


Figure 2: Automatic creation of the logic from a flow chart

In recent months and within the eContent STEEL project, CSC has developed new TEDDS® technology allowing Engineers to freely distribute standard TEDDS® calculations either internally within or externally to an organization. During the introduction of Eurocodes, TEDDS® Lite has the potential to revolutionise calculation development and use for Structural Engineers.

TEDDS® Lite is free software that can be downloaded from www.cscworld.com, it allows anyone to use calculations that have been developed and published for TEDDS® Lite.

Access Steel – a Case Study for simple calculation distribution

The introduction of Eurocodes is approaching and the STEEL Project has developed Access Steel (www.access-steel.com). This provides a single source of harmonised information relating to Eurocode steel design which is available across Europe.

The project is sponsored by the eContent programme of the EU and seven major steel producers (Arcelor, Corus, Peiner Träger, Ruukki, Voestalpine, Dillinger Htte GTS and SSAB). The harmonised information has been created by the project partners including SCI (UK), CTICM (Fr), Labien (Sp), RWTH (Ger), SBI (Swe), Pare (Lux), eTeams Industrial Ltd (Ire), CSC (UK) Ltd (UK), Arcelor (Lux), Corus (UK/Ne).

During the initial phase of the project, a User Needs Analysis was undertaken to assess what information about the Eurocodes the European Engineering industry required. Responses clearly indicated that worked examples would be one of the most beneficial information sources for Engineers, to assist with learning the new codes. In addition to traditional worked examples provided

In PDF format, the project also set out to provide much more flexible interactive worked examples. Having considered a number of alternative approaches, including spreadsheets, it was decided to use TEDDS® Lite as the platform for these Interactive Worked Examples.

The screenshot shows the TEDDS Lite software interface. The title bar reads "TEDDS Lite for Access Steel - [Simply supported beam with lateral restraint at load application]". The menu bar includes File, Edit, View, Tools, Window, and Help. The toolbar contains icons for New, Open, Save, Print, Header, Re-calculate, and Access Steel. The main content area is divided into several sections:

| | | | | | |
|------------|----------------------------|----|--------|--|----------|
| | Sheet | | 1 of 9 | | |
| | Title | | | | |
| | Interactive Worked Example | | | | |
| | Eurocode Ref | | | | |
| Made by | | BG | Date | | 6/5/2006 |
| Checked by | | CH | Date | | 6/5/2006 |

Simply supported beam with lateral restraint at load application point

Description

This worked example deals with a simply supported beam with lateral restraints at supports and at load application point.

The following distributed loads are applied to the beam:

- self-weight of the beam
- concrete slab
- imposed load

1 : Lateral restraint

The beam is an I-rolled profile in bending about the strong axis.

This example includes :

- the classification of the cross-section,
- the calculation of bending resistance, including the exact calculation of the elastic critical moment for lateral torsional buckling,
- the calculation of shear resistance, including shear buckling resistance,
- the calculation of the deflection at serviceability limit state.

Partial factors

| | | |
|-----------------|----------------------|--------------------------|
| Permanent loads | $\gamma_G = 1.35$ | EN 1990 |
| Variable loads | $\gamma_Q = 1.50$ | |
| | $\gamma_{M0} = 1.00$ | EN 1993-1-1 § 6.1 (1) |
| | $\gamma_{M1} = 1.00$ | |

Basic data

Design a non composite floor beam of a multi-storey building according to the data given below. Two secondary beams are connected to the calculated one at mid-span. The beam is assumed to be laterally restrained at mid-span and at the ends

Calculated by
CSC TEDDS^{lite}
www.tedds.com

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Figure 3: A typical worked example available on access-steel.com

The worked examples were initially written by different project partners using Microsoft Word™. A number of the worked examples were identified as being appropriate for conversion to interactive examples. TEDDS® was used to elevate the existing worked examples to be interactive. A total of 11 interactive worked examples were created, each example typically taking an Engineer less than a week to complete. As is the case for all the content of Access Steel, the Interactive Worked Examples are available in four languages – English, French, German and Spanish.

Developed in conjunction with the STEEL project, TEDDS® Lite has provided a cost effective platform for publishing interactive calculations to a potential audience of 150,000 Structural Engineers across Europe. The calculations themselves were written by Engineers for Engineers without the need for specialist software developers. The calculations are easy to follow, easy to check and will provide invaluable learning tools for the Eurocodes.

Conclusion

Engineers will continue to improve their efficiency, either by developing their own small scale electronic calculations to assist with repetitive calculations, or by using calculations developed by others.

In the past much of this development has been undertaken by Engineers in an unmanaged, unplanned, individualistic way by writing one-off spreadsheets on an ad-hoc basis.

The introduction of Eurocodes could bring about a repeat of the plethora of unplanned spreadsheets which will prove to be very difficult to quality assure and share.

TEDDS® Lite has the potential to provide you with a new solution that could revolutionise the process for creating simple to use, high quality and accurate calculations that can be shared throughout your organisation.

Now is the time to consider proper planning and management, otherwise the process of change will continue to repeat past mistakes and will not realise new possibilities.
