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Developments in TASEF

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TASEF / TASEFplus

OUTLINE

- TASEF and TASEFplus
  - Tempearture Distribution based on the Finite Element method
  - TASEF in education
  - TASEFplus features
- Recent work for SFPE
- Shadow Effect
- Conclusion

TASEF

TASEF is a finite element computer program for calculating temperature distributions in structures and materials exposed to fire. TASEF handles plane or axi-symmetric problems, that is, two dimensional problems.

TASEF was developed by my co-author, Ulf Wickström, while he was at Sweden's Fire Research Station (SP Research Institute).

At City University, TASEF was adopted, directly from a published report, as a means of calculating temperature distribution in a cross-section as a prelude to doing mechanical analysis.

TASEF - APPLICATIONS

Separate applications resulted in successful solutions for:

- Isolated steel beams and columns exposed to fire
  SOSMEF
  Research Fellow: N Jeyarupalingam

- Isolated composite beams and columns exposed to fire
  COMPSEF
  Kuldeep Virdi

- Skeletal semi-rigid steel and composite frames exposed to fire
  FAUST
  Research Fellow: P Ragupathy

TASEF IN EDUCATION

TASEF, SOSMEF and FAUST were adopted as teaching aids for an MSc module at City University.

Students found the original TASEF, developed on main frame computers, difficult to use as a tool because its data had to be input in the line-by-line style of old FORTRAN programs.

One MSc student developed, as a Master’s dissertation, an interface for TASEF using Visual Basic 6 (ca. 2000)

After a couple of years of exposing the MSc module students to the Visual interface, initial bugs in the program were, more-or-less, removed.

TASEF IN EDUCATION

TASEF was used in a similar way at Aarhus University in Denmark. (ca. 2008 onwards).

This came to the attention of the original author, Ulf Wickström, who was due to retire from SP and was taking up a position as Professor at Luleå University of Technology, Sweden.

He liked the user-friendly interface and saw a potential to market the program, subject to certain developments he had in mind.

Thus collaboration was born and the program TASEFplus emerged.

TASEFplus FEATURES

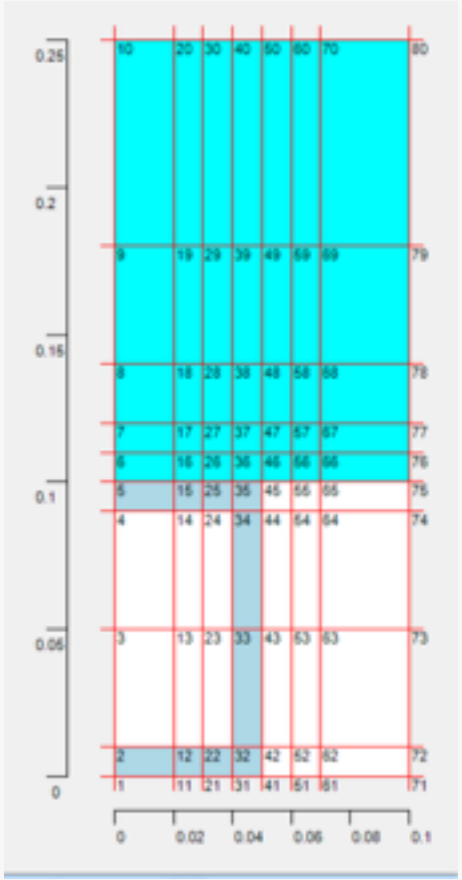
Geometry

- A simple, intuitive, approach for defining the finite element mesh.

- The meshing of the cross-section is shown by a graphical interface.

- Ability to visualise other input parameters.

- Features match those of more powerful software packages.



TASEFplus FEATURES

Fires and Boundary Conditions

- Standard fires are built into TASEFplus including ISO 834, EN 1363-1, parametric fire curves, the HC curve and ASTM E-119.

- Completely customized fires can also be specified. The program can handle several fires for various boundaries. These include typical fires defined by time temperature curves, incident heat flux by radiation combined with convection heat transfer from adjacent gases, as well as boundaries with prescribed temperatures.

- A special feature is the possibility to accurately model heat transfer by radiation and convection in voids.

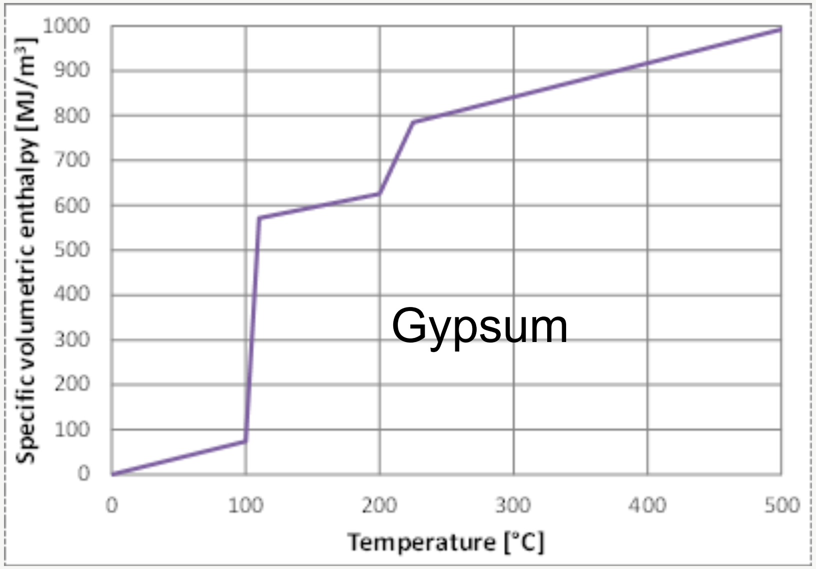
TASEFplus FEATURES

Thermal material properties

- Specific conductivity and specific volumetric enthalpy (density and specific heat capacity), can be specified as varying with temperature.

- Latent heat due to water evaporation can efficiently be modelled.

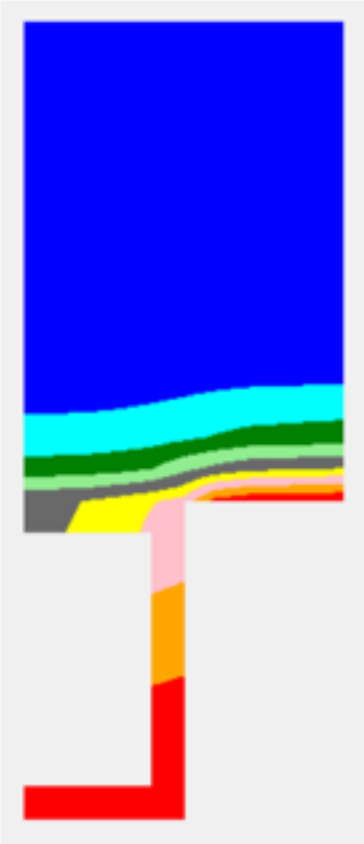
- Properties of steel, concrete and timber based on Eurocodes 2-5 are built into TASEFplus. Completely customised material properties can also be defined.



TASEFplus OUTPUT

Colour contours

- TASEFplus has the facility to view colour contours for the calculated temperature distribution.

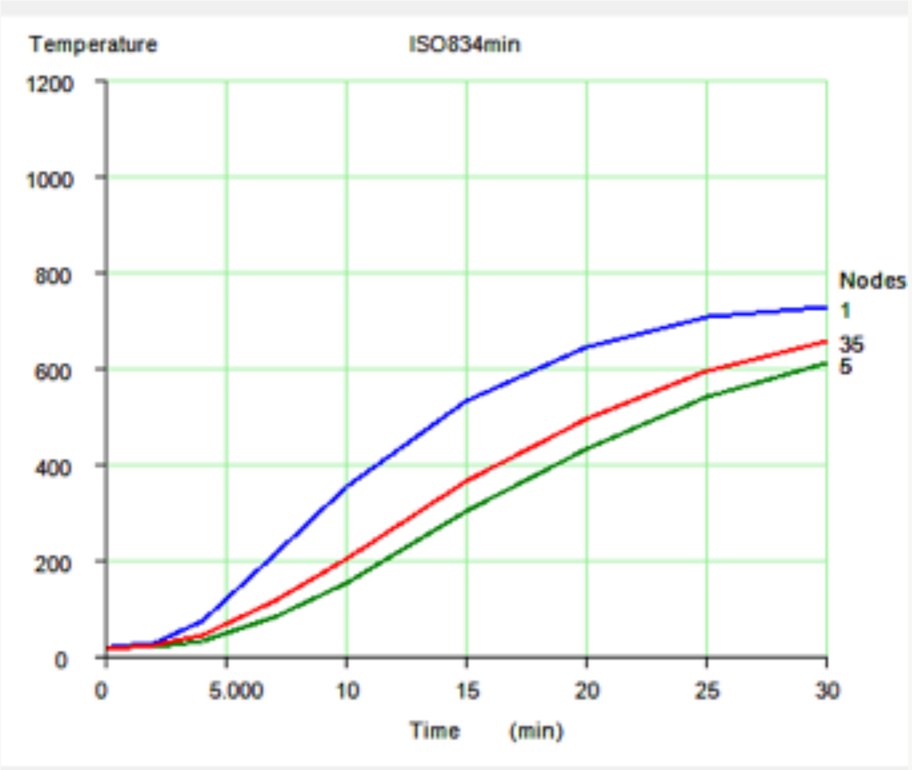


TASEFplus OUTPUT

Temperature-Time history

- Temperature-Time history of selected nodes in the cross-section can be plotted.

- In addition, a completely annotated text file output Is generated.



SFPE Standard

SFPE STANDARD

In 2012, a Task Group was formed by the SFPE Standards Making Committee for Predicting the Thermal Performance of Fire Resistive Assemblies

The aim was to develop a set of verification cases to be published in the SFPE Standard.

Two software packages were used for the calculations
- ABAQUS
- TASEF/TASEFplus

SFPE STANDARD

Task Group Report reference:

Ann Jeffers (University of Michigan)
Ulf Wickström (Luleå University/SP Research Institute)
Kevin McGrattan (National Institute for Standards and Technology)

Standard on the Development and Use of Methodologies to Predict the Thermal Performance of Structural and Fire Resistive Assemblies

Society of Fire Protection Engineers (SFPE), Bethesda, MD.
2013,

SFPE STANDARD

Approach to Developing a Standard Verification Scheme

- Compile existing verification problems and make necessary modifications to problem statements for consistency and completeness

- Develop new verification cases to address physics that are not captured by existing verification cases

- Derive solutions to all cases, ensuring that the published solution is within an acceptable degree of accuracy as verified by the two calculation methods (ABAQUS and TASEF/TASEFplus)

SFPE STANDARD

As an illustration, Case 9 (Composite Section) from the report shows:

Time (min)	EN 1991-1-1-2	TASEF	ABAQUS
0	0	0	0
30	341	343	341
60	717	722	723
90	882	885	886
120	951	952	953
150	979	980	981
180	992	992	992

SFPE STANDARD

Summary

- The report presents results from ABAQUS and TASEF compared with published results for a total of 16 cases.
- In all cases, as in the Case 9 shown above, both TASEF and ABAQUS gave results which differed by no more than ±1ºC from published results.
- TASEF compares extremely well with ABAQUS.

SHADOW EFFECT

SHADOW EFFECT

In fire engineering, it is recognised that the radiative heat exchange in unprotected steel I-sections is reduced due to geometric effects.

Most computations are based on the assumption that an I-section receives heat from convection and radiation uniformly over the entire surface area.

Since radiation is directional, the reduction in the heat transferred actually occurs because flanges cast a 'shadow' on the rest of the section.

SHADOW EFFECT

Ignoring the shadow effect leads to conservative results.

However, one consequence is that a given design may thus become uneconomic.

Based on some of the work of co-author Ulf Wickström, a much simplified approach appears in the fire engineering part of Eurocode 3 for steel structures.

In this presentation, temperature distributions in steel beams with or without considering the shadow effect are evaluated in a more rigorous manner.

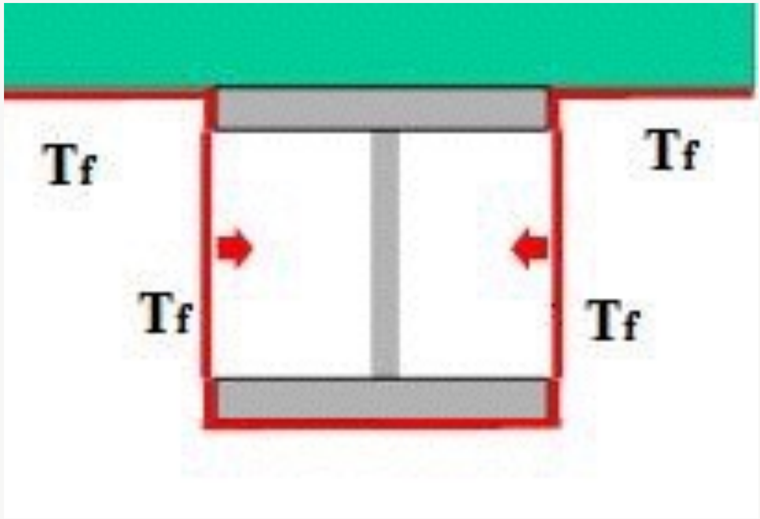
SHADOW EFFECT

Shadow effect may be considered by introducing an artificial boundary on the 'open' sides of the I section, that is, in the space between the flanges.

The introduced boundaries follow the same fire curve as the rest of the section.

The key feature of this artificial boundary is that it is specified to follow the fire temperatures.

In this way, it does not cause radiation to pass through, thus introducing a shadow



EXAMPLE

An idealised steel HEA400A section supports a 200mm concrete floor (no composite action).

Beam depth	400mm
Width	300mm (Half width 150mm)
Flange thickness	40mm
Web thickness	30mm

Thermal properties of steel and concrete are in accordance with Eurocode 3 and Eurocode 2, respectively.

ISO fire applies on the underside of the floor.

EXAMPLE

Surface emissivity for both steel and concrete is assumed to be 0.8.

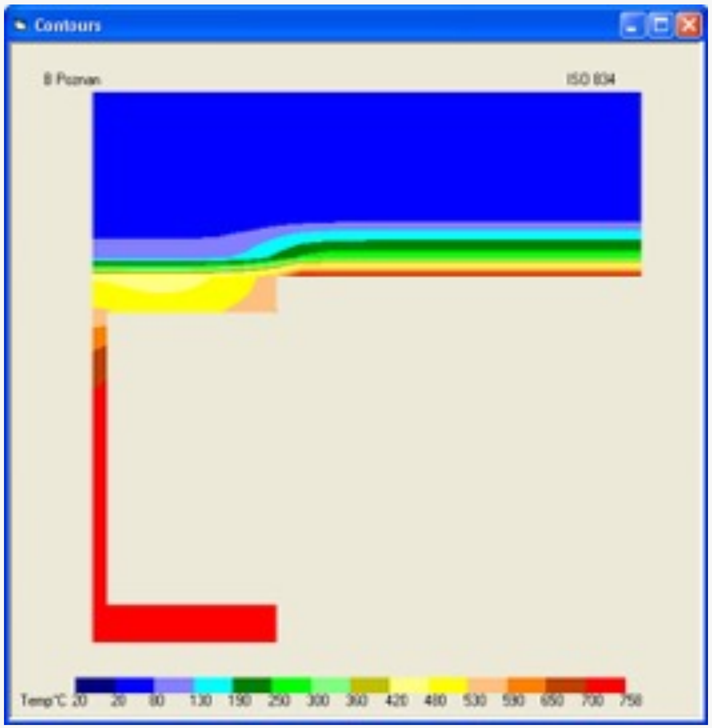
The artificial boundary introduced is one element wide of dimension 10mm.

The temperature of the inside surface of the artificial boundary is then prescribed to follow the fire time-temperature curve.

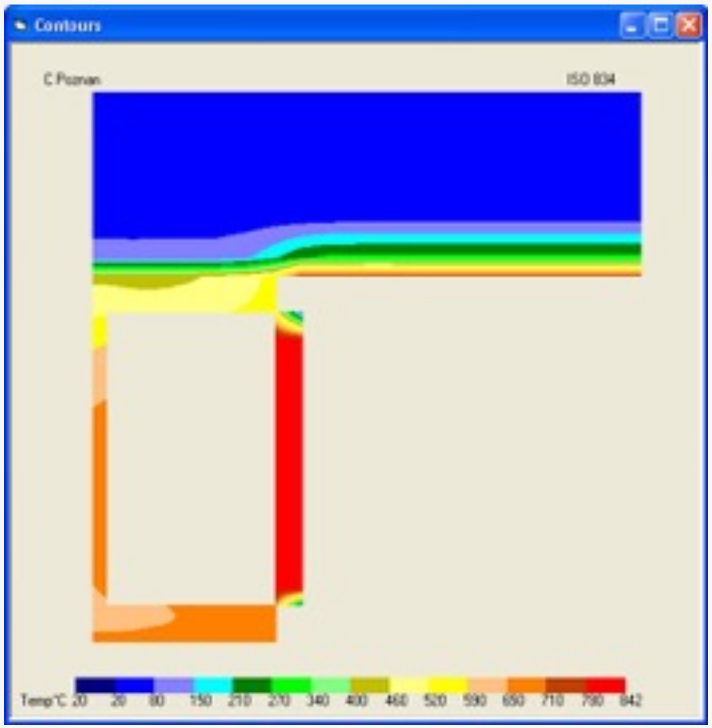
The emissivity of the artificial surface is taken as unity.

TEMPERATURE DISTRIBUTIONS AT 30 min

No Shadow Effect

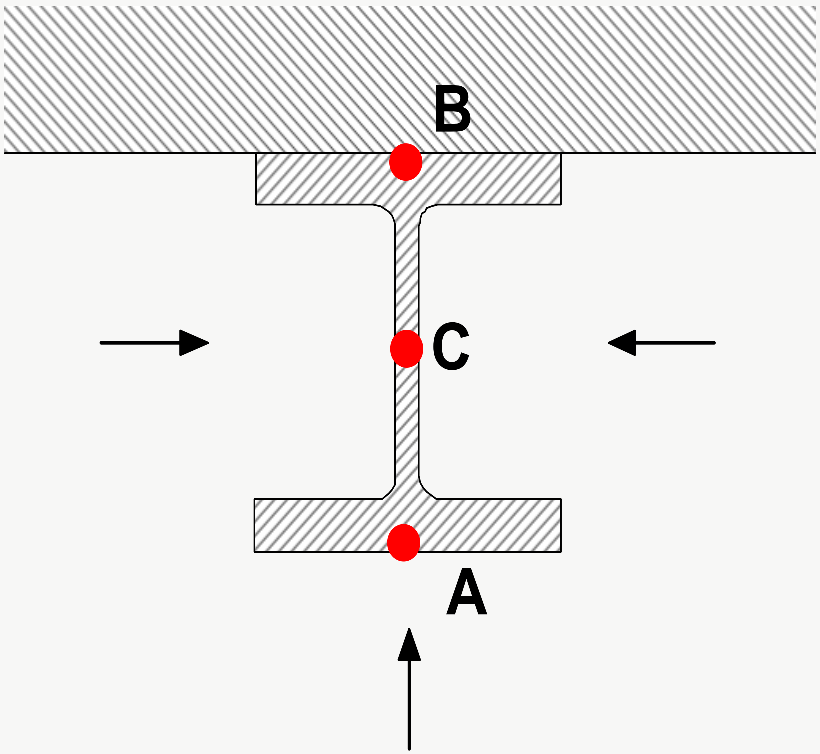


With Shadow Effect



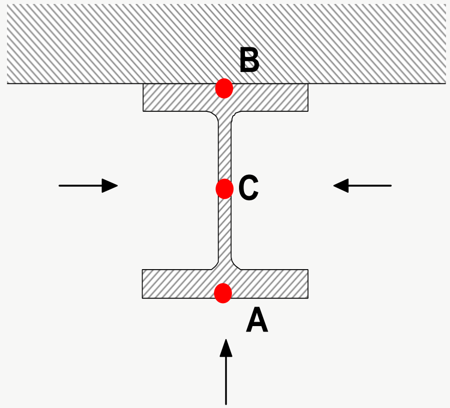
TEMPERATURE DISTRIBUTIONS AT 30 min

Points selected for comparison of temperatures



TEMPERATURE DISTRIBUTIONS AT 30 min

Position	Eurocode 3	No Shadow Effect	With Shadow Effect
A	827`	709	661
B	827`	544	510
C	827	714	666



Rigorous analysis gives lower temperatures than Eurocode 3.

The reduction in temperatures is first due to the transmission of heat into the concrete slab supported by the beam, a feature not taken into account in Eurocode 3.

Consideration of Shadow Effect gives further reduction in temperatures.

EXAMPLE

The reduction in calculated temperatures, when taking Shadow Effect into account, would lead to a longer fire duration for a given load or a higher load carrying capacity for the same fire duration.

This is examined next.

MECHANICAL RESPONSE

The structural response of the I-beam for temperature distributions with and without the shadow effect has been analysed by the program COMPSEF,

COMPSEF carries out structural analysis using temperature dependent material properties.

The program uses thermal distributions directly imported from TASEF.

COMPSEF considers the equilibrium of the beam (or a column) under a given loading for progressively increasing fire time steps.

The maximum time for which an equilibrium deflected shape is calculated, is taken as the fire duration.

MECHANICAL RESPONSE

The span of the beam is taken as 3m. The beam is subjected to a uniformly distributed gravity load of 300kN/m.

As there is no composite action between the beam and the concrete above, this analysis considers the steel section alone.

Results from COMPSEF are given below.

No Shadow Effect	With Shadow Effect
30.0min	35.4min

This is a significant gain in fire duration.

CONCLUSION

CONCLUSION

The presentation has described TASEF and its interface program TASEFplus.

A recent study for SFPE used TASEF as a benchmark program, alongside ABAQUS, with the aim of developing a set of verification cases to be published in the SFPE Standard.

The presentation described how the shadow effect can be taken into account in determining the temperature distributions in a steel beam exposed to fire.

The reduction in temperatures is first due to the transmission of heat into the concrete slab supported by the beam, a feature not taken into account in Eurocode 3. Further significant reductions in temperatures are obtained by considering the Shadow Effect

CONCLUSION

The resulting improved structural performance, calculated by the finite difference based program COMPSEF, is reflected in the increase in time to failure from 30.0 min to 35.4 min due to the shadow effect.

This difference could be significant in many practical situations.

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