LUSAS

Infrastructure design software

NEW FEATURES AND ENHANCEMENTS

Version 18

In detail...

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LUSAS Version 18

LUSAS Version 18 sees the introduction of a new software option for reinforced concrete frame design. The Traffic Load Optimisation option has been extended to cover rail (train) loading, and the Heat of Hydration option now allows for advanced concrete hygro-thermal/structural analysis.

Steel frame design options, and prestress capabilities are also extended; concrete creep and shrinkage, and geotechnical material models are enhanced; design-code based load combinations have been updated; and further transparency is provided allowing you to drill-down into combination and envelope results to see just how the final factored load effect has been obtained.

RC Frame Design

- Carry out design checks of reinforced concrete decks/beams and piers/ columns subject to bending and axial force.
- Define reinforcement details for any regular or arbitrary shaped section.
- Define lengths over which the reinforcement arrangements act.
- View utilisation results for selected design load groups and locations
- View results on the model, in tabular format, or as an interaction surface diagram.
- Add selected results to a model report.

Enhanced Rail Tools

- Obtain more efficient and economic design, assessment or load rating of rail bridge structures.
- Define track paths and widths and combine any number of tracks to create loadable track layouts.
- Restrict loading to specific locations on a track to represent stationary trains at signals for example.
- Run a Direct Method Influence analysis to identify most onerous train loading arrangements for a track layout.
- Reduce time spent manually replicating train loading patterns.

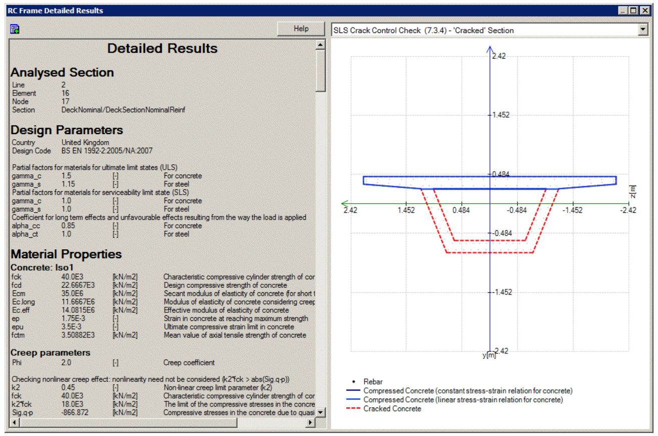
Advanced Concrete

- Use hygro-thermal analysis to model time (hydration) dependent concrete behavior from casting to old age.
- Model formwork and environment effects on the heat and moisture transfer to and from the concrete.
- Predict the internal heat generation as the concrete cures and identify temperature gradients.
- Compute shrinkage as it cures.
- Couple hygro-thermal analysis with a structural analysis to determine time- and age-dependent deformations, stresses, crack-widths and more.

Reinforced Concrete Frame Design (New software option)

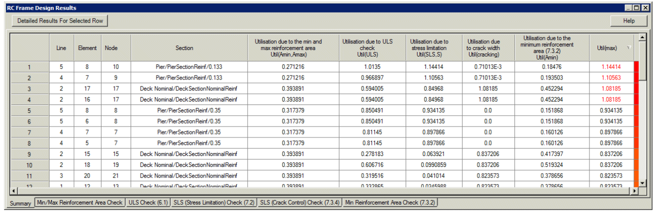
Capabilities

Design code checking of regular and arbitrary shaped reinforced concrete beams and columns (likewise, decks and piers) with or without voids can now be easily carried out in LUSAS Modeller. This is performed as a results processing operation following the solving of a model, and requires the inclusion of reinforcement arrangements within the geometric line attribute as well as the assignment of design code specific RC frame design attributes to lines in the model that represent concrete members.



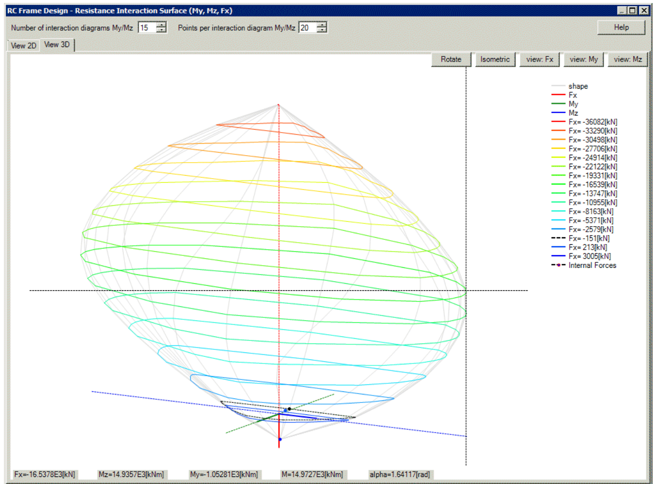
The following design codes are currently supported:

- **EN1992-1:2004** - EN 1992-1-1:2004 +A1 Eurocode 2: Design of concrete structures Part 1-1: General rules and rules for buildings.



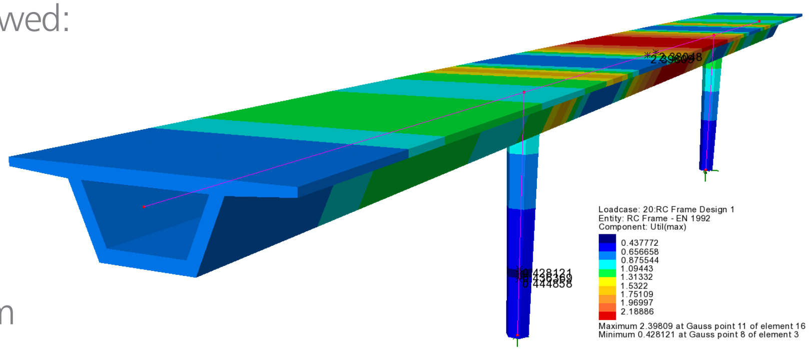
- **EN1992-2:2005** - EN1992-2: 2005 Eurocode 2: Design of concrete structures Part 2: Concrete bridges - Design and detailing rules.

Design checks due to bending with or without axial force can be carried out for reinforced concrete sections at the Ultimate Limit State (ULS) and Serviceability limit states (SLS).



RC Frame Design results can be viewed:

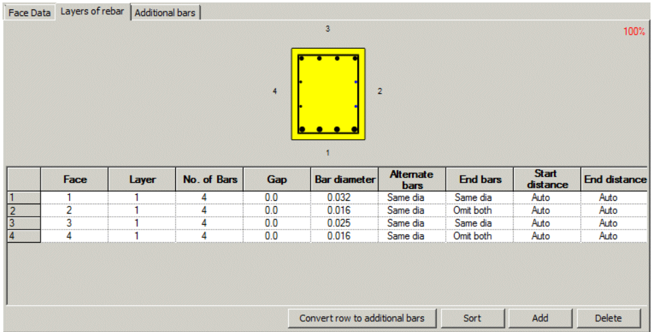
- On the model
- Using the print results wizard
- In tabular format
- As an interaction surface diagram

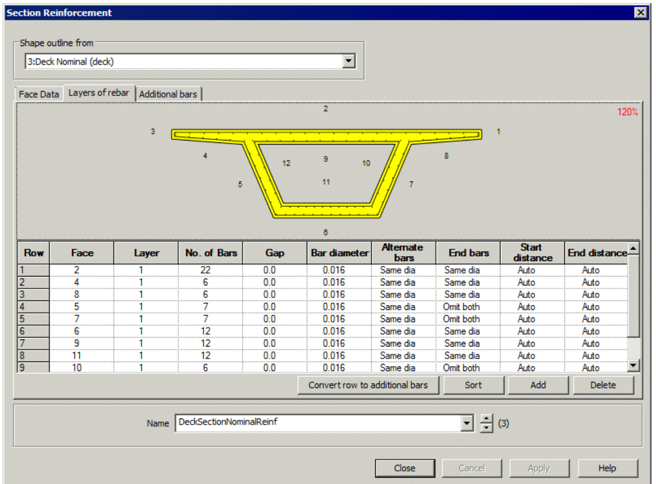


Section reinforcement

Section reinforcement defines the main bar arrangements to be provided in a member's cross-section. It can be defined for any standard or arbitrary shape, with or without voids. Tapering members are also supported.

Section reinforcement utilities are referenced by line reinforcement utilities.

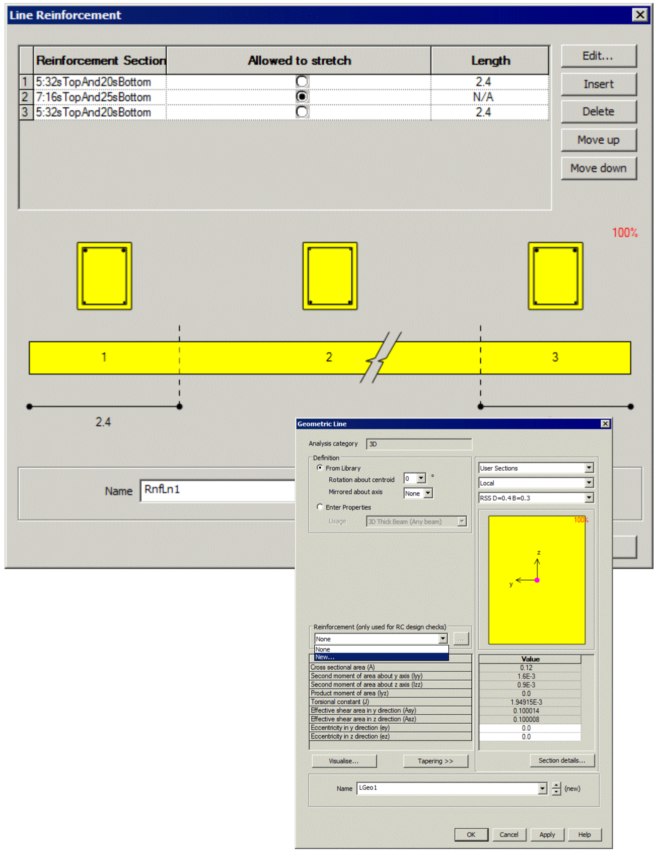




Line reinforcement

Line reinforcement is used to specify how individual section reinforcement arrangements apply over a length of a line or lines representing a concrete member.

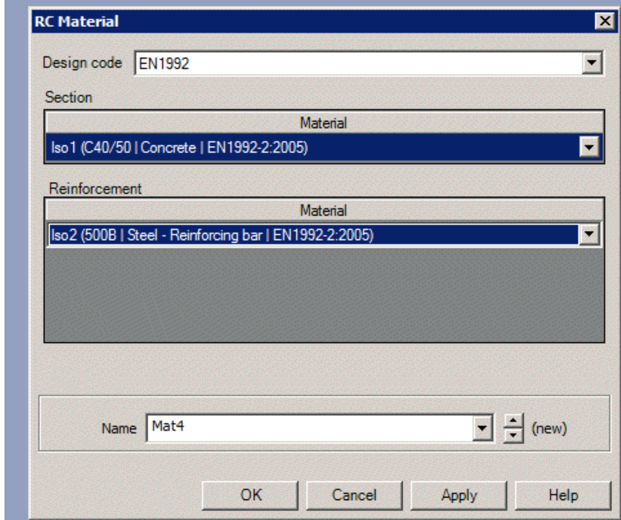
Line reinforcement is referenced by geometric line beam attributes (that define the concrete section size/shape and properties for a member).



Reinforced concrete compound material model

A new reinforced concrete compound material model has been introduced for use with the RC frame design facility.

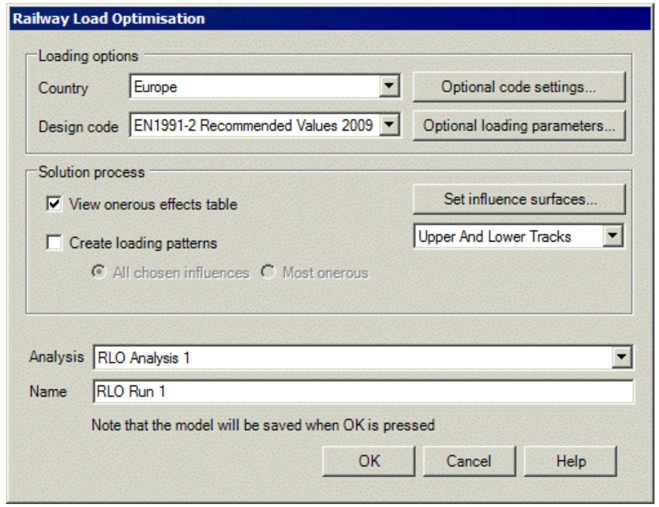
This material references linear elastic concrete and steel materials provided in the standard Material Library and permits the assignment of both materials to a single line feature within Modeller.



Rail Load Optimisation (included in Traffic Load Optimisation option)

Capabilities

The LUSAS Traffic Load Optimisation software option has been extended to provide Rail Load Optimisation. This provides the means to define parameters for a particular design code, and generate the most critical rail track loading pattern for a selected track layout, for each influence shape under consideration.



Rail Load Optimisation currently supports track loading to:

- **Eurocode EN1991-2 (Recommended values) and National Annexes for Denmark, Finland, Ireland, Italy, Norway, Poland and the United Kingdom**
- **International UIC Leaflet 776-1 (5th Edition)**
- **United Kingdom NR-GN-CIV-025**

The paths of railway tracks and viable track layouts must be specified.

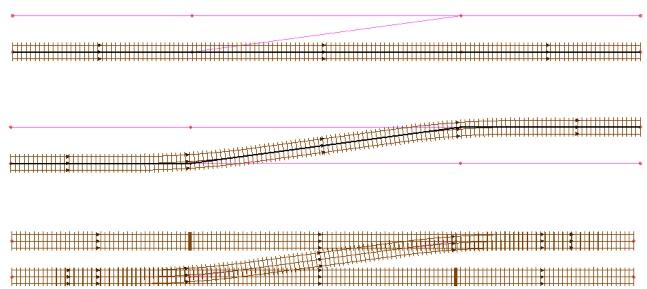
Track definitions

Track definitions are used by rail track layouts to specify particular track loading scenarios for use with the Rail Load Optimisation facility. The centrelines of segments of track can be defined by coordinates, or be copied and pasted from a spreadsheet, or (more usually) be defined from selected lines and arcs that are drawn to represent the track centrelines in the LUSAS model. The transverse distance between rail loads on the track must also be stated.

Once defined, a track is shown on the model by the drawing of additional lines to represent the rails and sleepers. The rail track definition is stored and viewed in the Utilities Treeview. Like other utilities, track definitions are not directly assignable to geometry and can only be edited using the track definition dialog.

Track layouts

A rail track layout defines which track definitions can be loaded simultaneously in a Rail DMI analysis. Multiple track layouts can be defined.

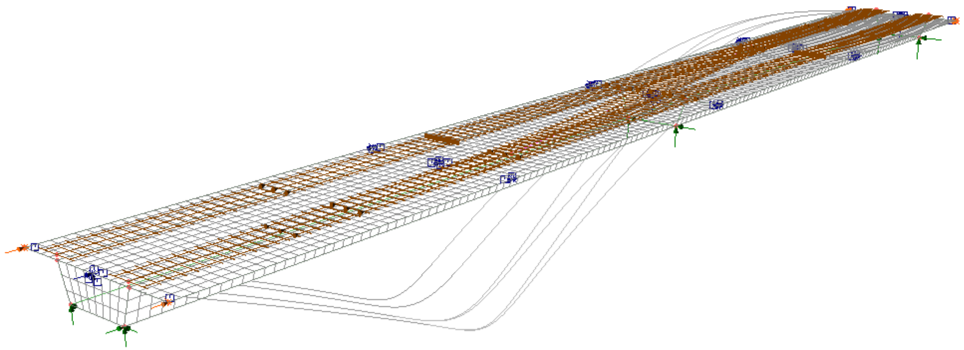


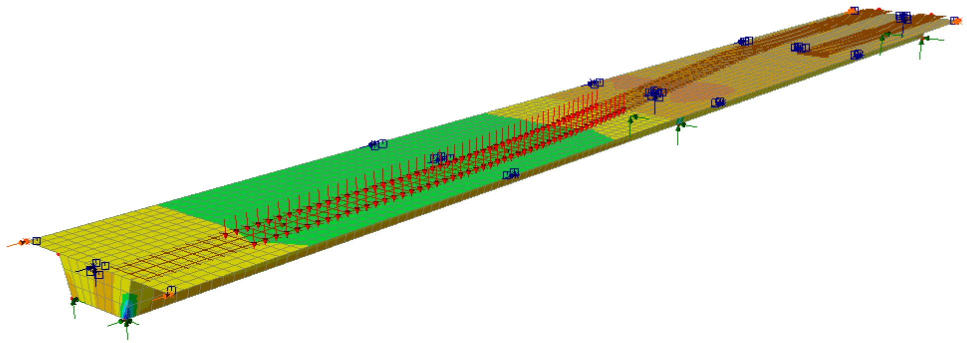
Design codes supported by LUSAS TLO

- Australia: AS5100-2: 2004, AS5100-7: 2004 (Austroads)
- Canada CAN/CSA-S6-06 (Design)
- China: JTG D62-2015
- Denmark: DS/EN 1991:2 DK NA:2015
- Europe: EN1991-2 Recommended values
- Finand: EN1991-2
- Ireland: EN1991-2
- Italy: EN1991-2
- New Zealand (Transit New Zealand Bridge Manual)
- Poland: EN1991-2
- Saudi Arabia: MOMRA Bridges Design Specifications
- Sweden: EN1991-2 (2009), EN1991-2 (2011), TDOK 2013:0267 Version 3.0
- South Africa: TMH7
- International UIC Leaflet 776-1 (5th Edition)
- United Kingdom: EN1991-2, BA34/90, BD21/01, BD37/01 (Road+Rail), BD86/11, BS5400 Rail Railtrack document RT/CE/025, NR-GN-CIV-025
- United States of America: AASHTO LRFD (7th and 6th Edition) and AASHTO Standard Specifications (17th Edition)

Direct Method Influence Analysis for Rail

The DMI analysis capability has been enhanced for use with the Rail Load Optimisation facility. Instead of the grid of virtual points that is used by the Vehicle Load Optimisation facility to represent the loadable region of a deck that is to be loaded with a unit point load as part of an influence analysis, for a Rail Direct Method Influence analysis, nodes are created automatically where each rail intersects with an element in the search area. In this way, the number of locations where a unit load can be applied is minimised, and ensures that the influence shapes are drawn following the alignment of each rail track.

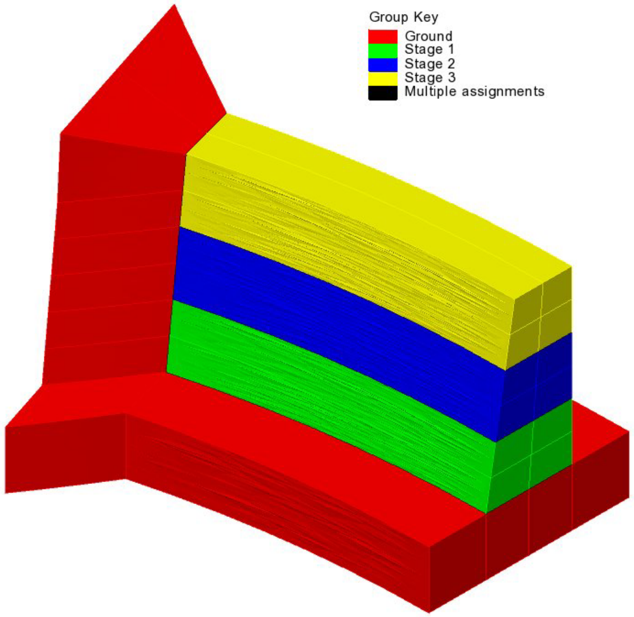




Hygro-thermal analysis (included in Heat of Hydration software option)

Usage

A hygro-thermal or coupled hygro-thermal/structural analysis can be set-up via the New Model dialog, or by adding a hygro-thermal analysis to a structural analysis, or vice-versa. A Hygro-thermal / Structural coupled analysis can model the time (hydration) dependent behaviour of concrete from time of casting to old age.



Capabilities

- Take into account the time dependent environmental conditions when the concrete cures, such as daily cycles of temperature and humidity, to the desired degree of detail.

- Model the effect the formwork (and environment) has on the heat and moisture transfer to and from the concrete

- Predict the internal heat generated as the concrete cures so that any excessive temperature gradients that might cause the concrete to crack can be identified.

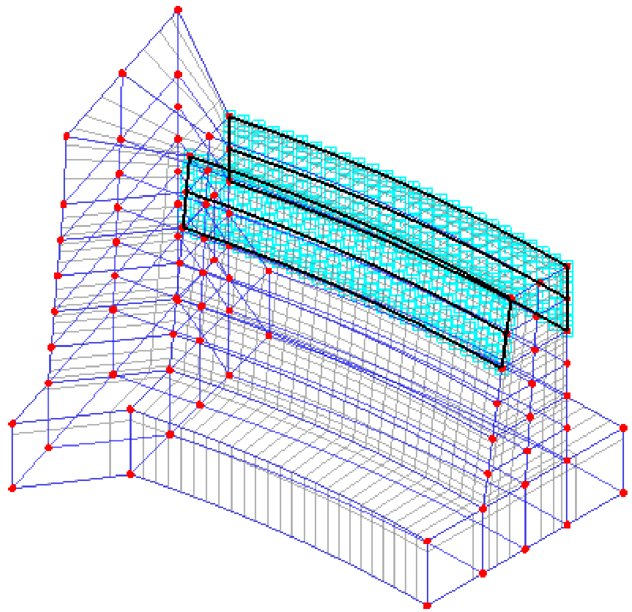
- Compute the amount of shrinkage in the concrete as it cures via the migration of moisture and the degree of saturation.

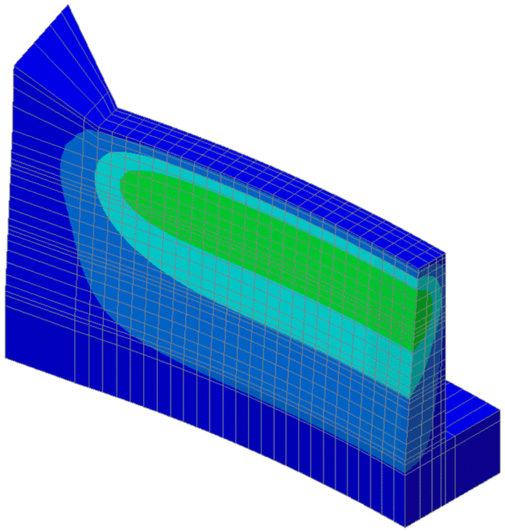
- Take into account into account the creep strains that occur during cure as the concrete is stressed.

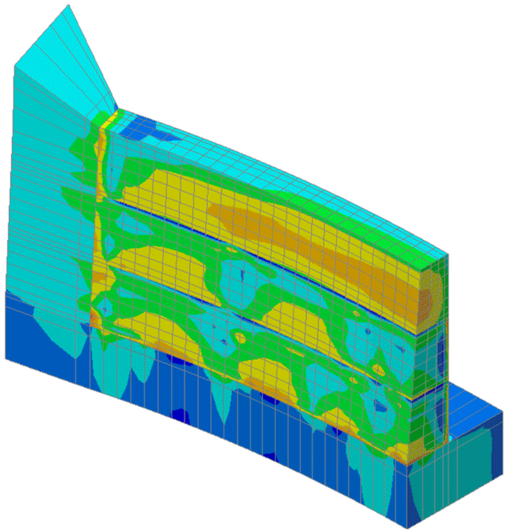
- Model the evolution of properties E, fc, and ft.

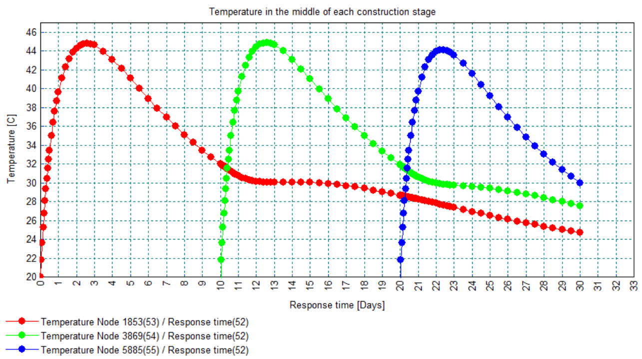
- Predict failure when the concrete is fully (or partially) cured, and if the mesh is fine enough, obtain reasonable estimates of crack widths.

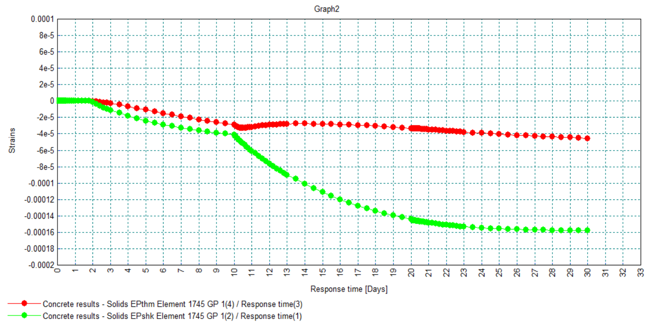
It is for use when concrete temperatures are under 100 degrees Celsius, as it assumes that the pore pressure remains constant (i.e. the rate of pore water evaporation is low in comparison to the rate of water vapour migration in the porous network).

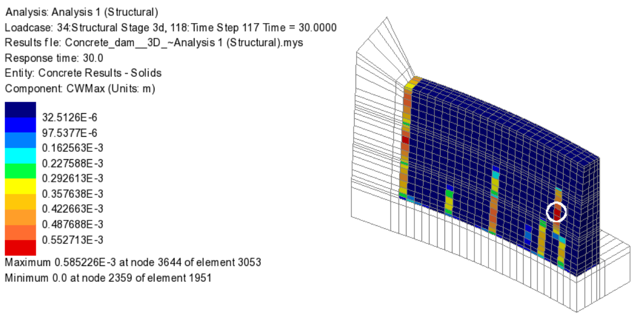


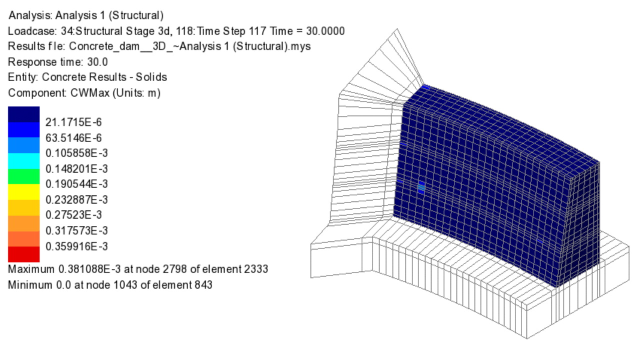












Related new hygro-themal analysis facilities

- 2D, 2D axisymmetric and 3D startup templates are provided.
- Hygro-thermal isotropic materials can now be defined, which is applicable to all thermal elements except thermal links.
- A range of hygro-thermal load types is provided.
- Prescribed temperature and relative humidity ‘supports’ can be defined.

Assign environmental temperature within a load curve analysis

If external fluid (air) temperature and/or associated convection and/or radiation heat transfer coefficients and/or environmental relative humidity and/or water vapour mass transfer coefficients vary in time, pre-defined or new 'on-the-fly' load curves can be specified on the Environmental conditions assignment dialog in order to vary each of the values accordingly.

Steel Frame Design improvements

AASHTO LRFD 8th edition

The steel frame design software option now supports AASHTO LRFD 8th edition. The scope of the checks to the 8th Edition is also greater than that of the previously implemented 7th Edition, covering:

- Shear checks for members with transversely stiffened webs – with provision for different end panels and interior panels
- Design checks for S-series (rolled standard beams)
- Design checks for equal-thickness angle sections with a leg ratio <1.7 (for axial loads only)
- Option for user-defined buckling lengths
- The method for checking nonslender members subject to combined compression and flexure of Article 6.9.4.2.1 has been implemented
- Inclusion of ASTM A1085 product standard for hollow sections (new in the 8th Edition)

AS4100

Steel frame design checks to AS4100 now include axial load checks for equal and unequal angles.

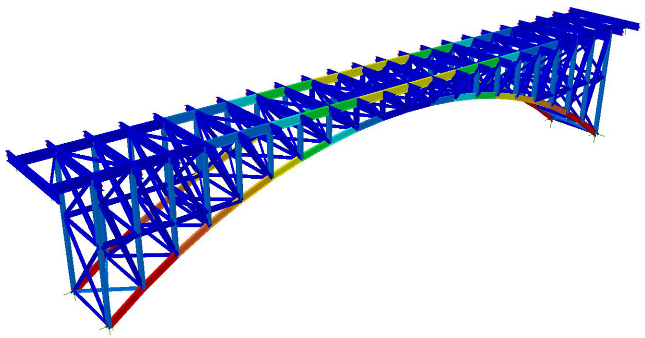
Checks for angle sections are limited to Util(Fxt) - utilisation for tension, Util(Fxc) - utilisation for compression, Util(Fx)c,by) - utilisation for compression member about the y-axis, and Util(Fx)c,bz) - utilisation for compression member buckling about the z-axis.

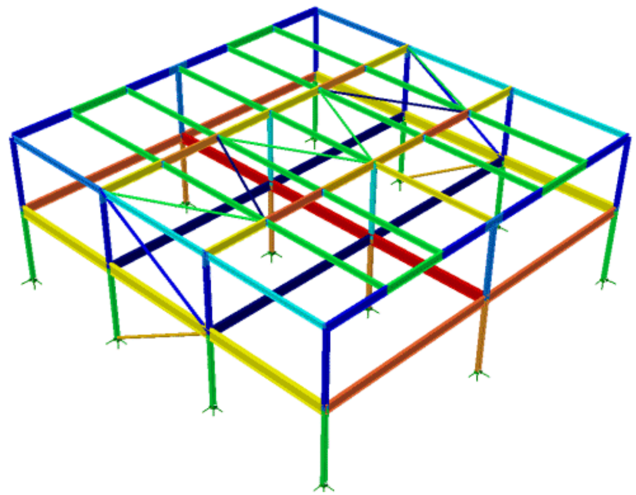
EN1993-1-1 and EN1993-2

Steel frame design checks to EN1993-1-1 and EN 1993-2 now include axial load checks for Class 3 angles.

A user defined length has been included for buckling lengths, and a length for lateral torsional buckling is now explicitly defined. Lateral buckling details for earlier LUSAS models are based on the minor axis buckling details.

The EN1993-2 implementation now supports Italy (UNI-EN 1993-2/NA:2007) and Spain (AN/UNE-EN 1993-2:2013)





AISC9 sections updated

Section library shapes and properties for the following have been updated to include properties for sloping flanges:

- S Shapes, C Standard Channels , MC Miscellaneous Channels, TS Tees from S Shapes.

Other enhancements

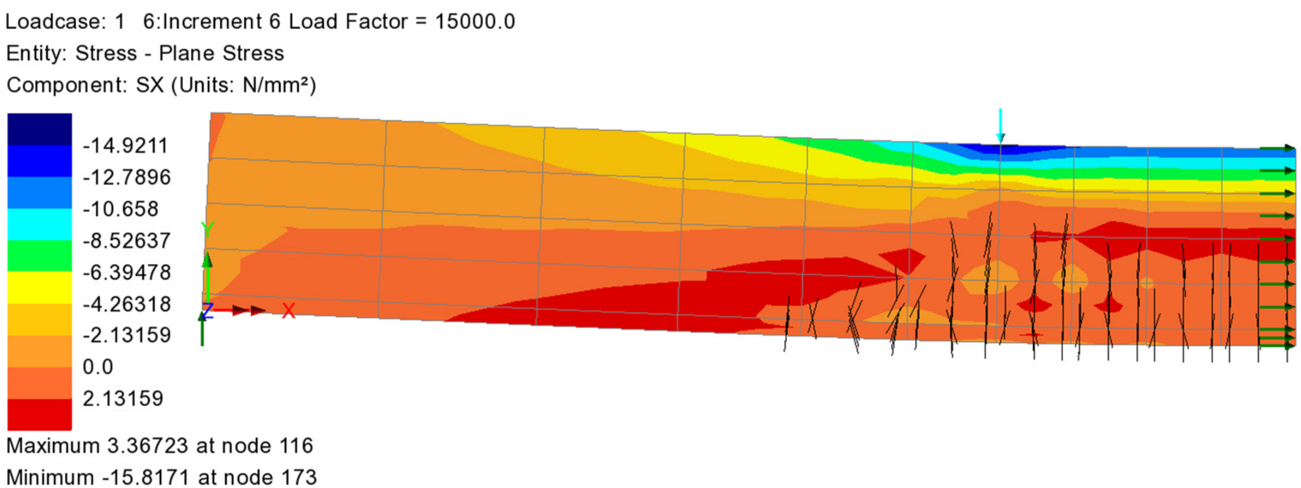
Codified concrete creep material with cracking

LUSAS has long been known for its advanced analysis capabilities, with a concrete cracking and crushing material model developed over many years in collaboration with top researchers in the field.

Version 18 brings that technology together with the time-dependent creep and shrinkage concrete material model in a single, flexible, 'Nonlinear Concrete' material. You can now choose to include or exclude cracking and crushing, and choose creep and shrinkage to a range of codes of practice.

The new transient smoothed concrete material model (model 105) is fundamentally the same as the smoothed concrete material model (model 109), but can only be accessed if a hygro-thermal/structural coupled analysis is specified.

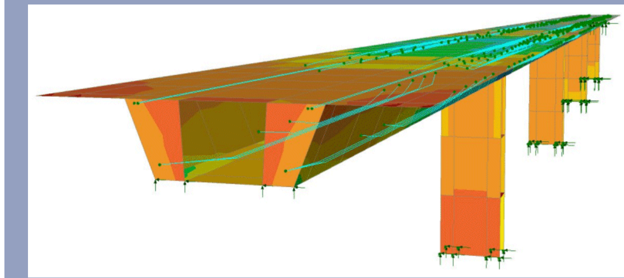
The material model takes into account the effects of heat of hydration, creep and shrinkage, along with the hydration dependent evolution of properties E, fc and ft.

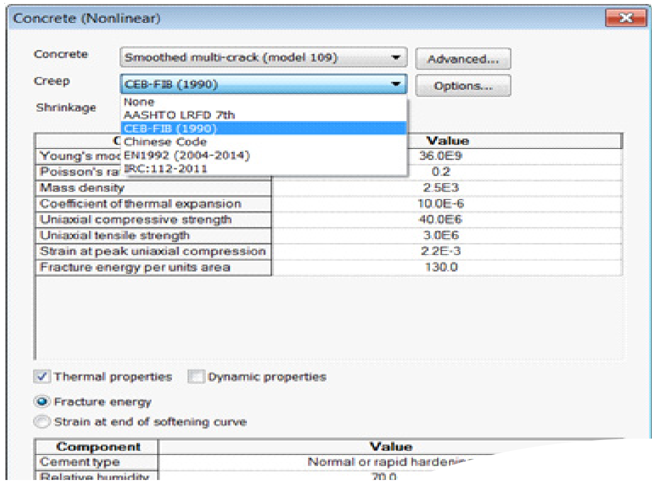


IRC:112-2011 prestress

Time dependent prestress can now be carried out in accordance with India code IRC:112-2011.

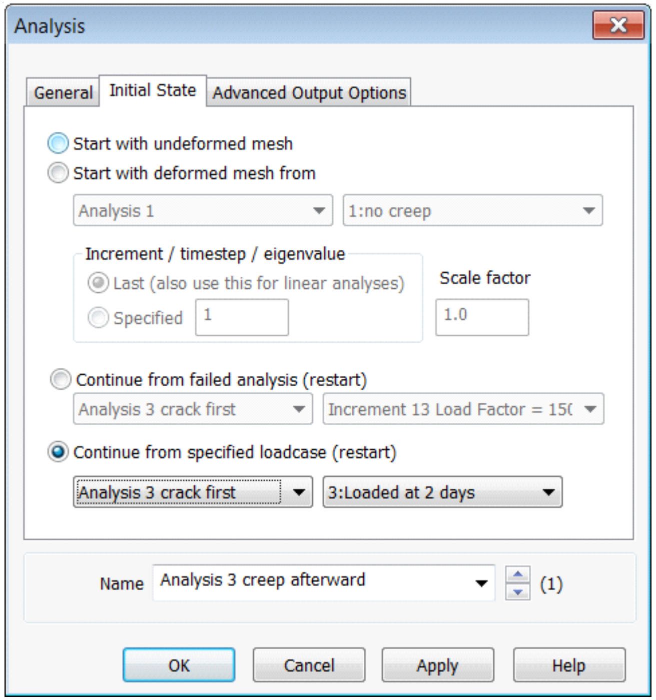
Other codes currently supported include AASHTO, CEB-FIP (1990), Chinese Code, and EN1992 (2004-2014)





Restart facility supported by LUSAS Modeller

The Modeller restart facility enables failed or terminated nonlinear or time-step analyses to be restarted from the last saved increment or, alternatively, if a solution is to be deliberately continued from a specified stage reached in a previous solution, from a specified loadcase. This allows for different settings to be specified to try and complete the analysis without requiring the full analysis to be re-solved in its entirety.



Mohr-Coulomb friction interface material

The Mohr-Coulomb friction interface element complements existing facilities for soil analysis and allows for more accurate modelling of strain hardening, softening and dilatancy at a soil/structure and soil/soil interfaces.

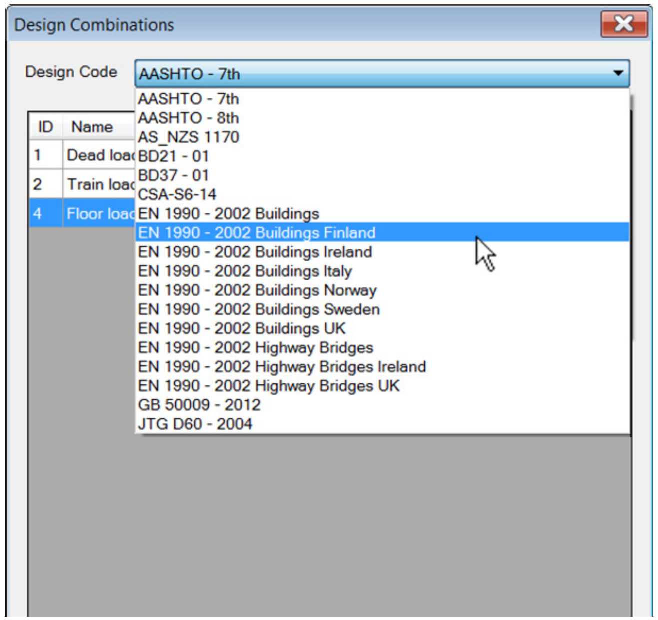
The Mohr-Coulomb interface material can be used in conjunction with 2D and 3D interface elements. It permits the modelling of a standard elastic-plastic sliding interface as well as strain hardening, softening and dilation.

The classic Mohr-Coulomb relationship is used to define failure conditions on the interface, and the slip at the interface is used to control the rate of dilation as well deterioration in the angle of friction. Cohesion can also be linked to the slip.

Additional design load combinations

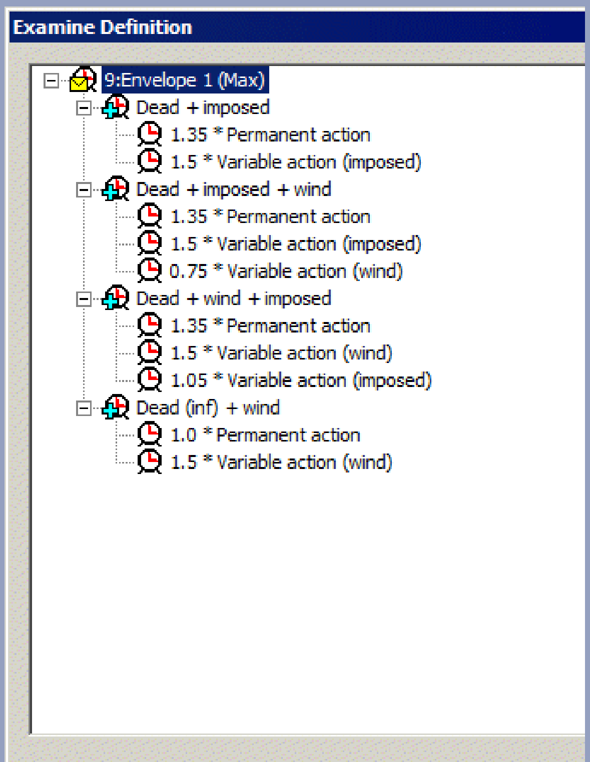
Design code based load combinations can now be created in accordance with the requirements of the EN1990 National Annexes of Finland, Italy, Norway and Sweden.

Separate Design Combination parent folders are created for Basic and Smart Combinations in the Analyses Treeview, containing folders holding the SLS Characteristic, SLS Frequent, SLS Quasi-permanent, and ULS Persistent (Eq 6.10) load combinations.



Examine the definition of a combination or envelope

By selecting the **Examine definition** context menu item for a combination or envelope entry in the Analyses Treeview, the nested combinations and envelopes that make up the definition can be viewed, together with the corresponding factors for each included loadcase.

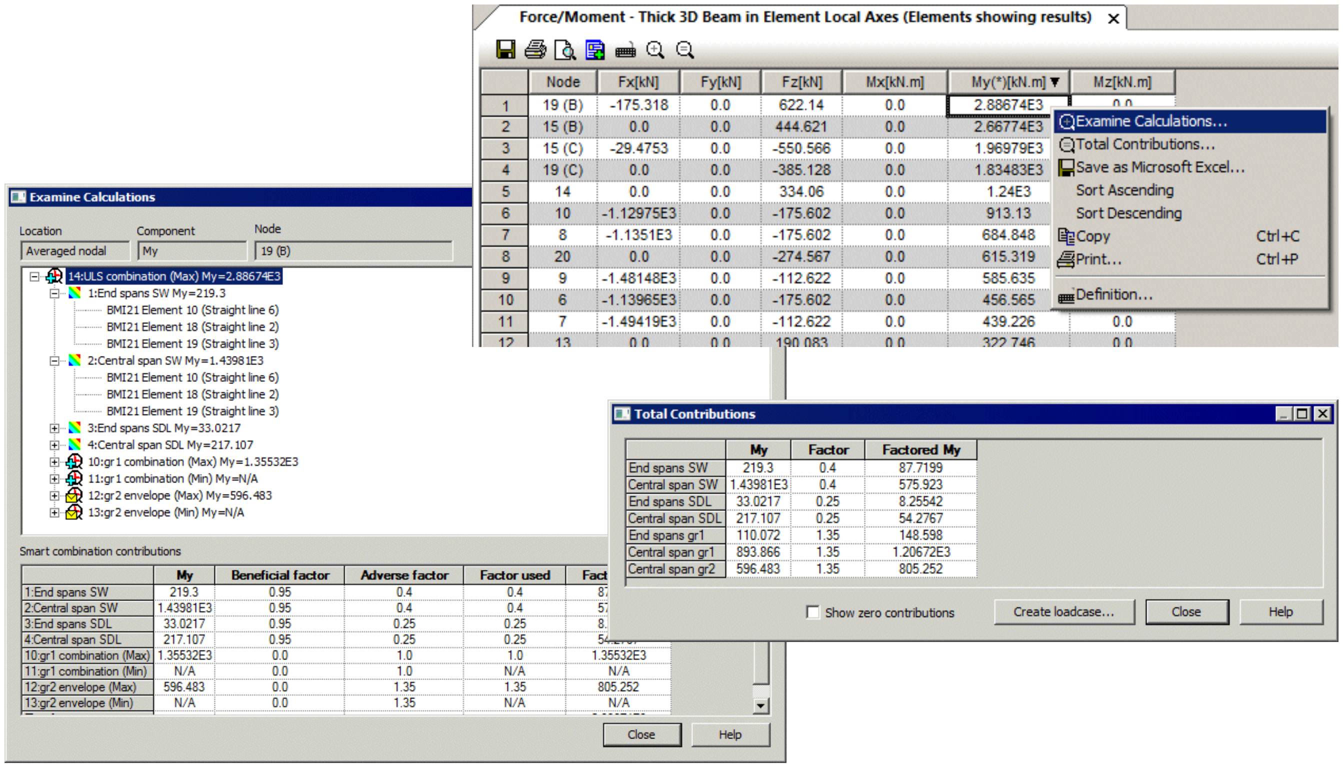


Examine computed results for combinations and envelopes

Two new selections are available in the Print Results Wizard's results output table to allow users to examine and show how a selected combination or envelope or other loadcase result has been obtained.

■ Selecting the **Examine Calculations** icon shows how a selected value has been calculated by listing the envelopes, combinations or loadcases, and the values from each, along with the relevant factors applied, that produce the selected result.

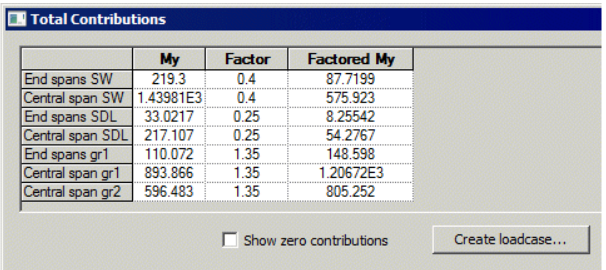
■ Selecting the **Total Calculations** icon reduces the contributing envelopes and combinations to a single table of loadcases and factors in use. Where it is notionally valid to sum the contributing unfactored load effects, these values are also listed in the table generated.



Loadcase from a smart combination result

When viewing print results wizard output for a smart combination, a loadcase can be created which includes all the loading assignments and factors which gave a particular result (at a particular node).

This is done by clicking the 'Create loadcase' button on the Total Contributions dialog. This may be useful for various reasons including when engineers wish to use an onerous loadcase identified by a linear analysis as part of a further nonlinear analysis.



	My	Factor	Factored My
End spans SW	219.3	0.4	87.7199
Central span SW	1.43981E3	0.4	575.923
End spans SDL	33.0217	0.25	8.25542
Central span SDL	217.107	0.25	54.2767
End spans gr1	110.072	1.35	148.598
Central span gr1	893.866	1.35	1.20672E3
Central span gr2	596.483	1.35	805.252

Element library

Hygro-thermal elements

■ **New 2D plane hygro-thermal elements (THT3,6 and QHT4,8)** - used for analysing continuum problems involving the heat of hydration and/or drying (wetting) of concrete when behaviour is essentially two dimensional. These elements are normally used in a hygro-thermal-structural coupled analysis. They can be coupled with plane strain structural elements (since the heat/moisture exchange over the area of the element would have effect only near both ends of the 'infinite' thickness), or with thin, plane stress elements, when they are ideally isolated on both sides of their area.

■ **New 2D axisymmetric hygro-thermal solid elements (TXHT3,6 and QXHT4,8)** - used for analysing continuum problems involving the heat of hydration and/or drying (wetting) of concrete, which exhibit geometric and loading symmetry about a given axis. These elements are normally used in a hygro-thermal-structural coupled analysis.

■ **New 3D solid hygro-thermal elements (THT4,10, PHT6,12,15 and HHT8,16,20)** - used to analyse continuum problems where the response is fully 3D (i.e. it cannot be approximated using the plane or axisymmetric elements). These elements are generally used for problems involving the heat of hydration and/or drying (wetting) of concrete, and are normally used in a hygro-thermal-structural coupled analysis.

Interface element for soil-structure interaction modelling

■ **New 2D (IPN6P and IAX6P) and 3D (IS12P and IS16P) two phase interface elements** - used for modelling standard Mohr-Coulomb friction contact in soil/structure and soil/soil interactions.

New worked examples

These new worked examples illustrate some of the new facilities in Version 18.

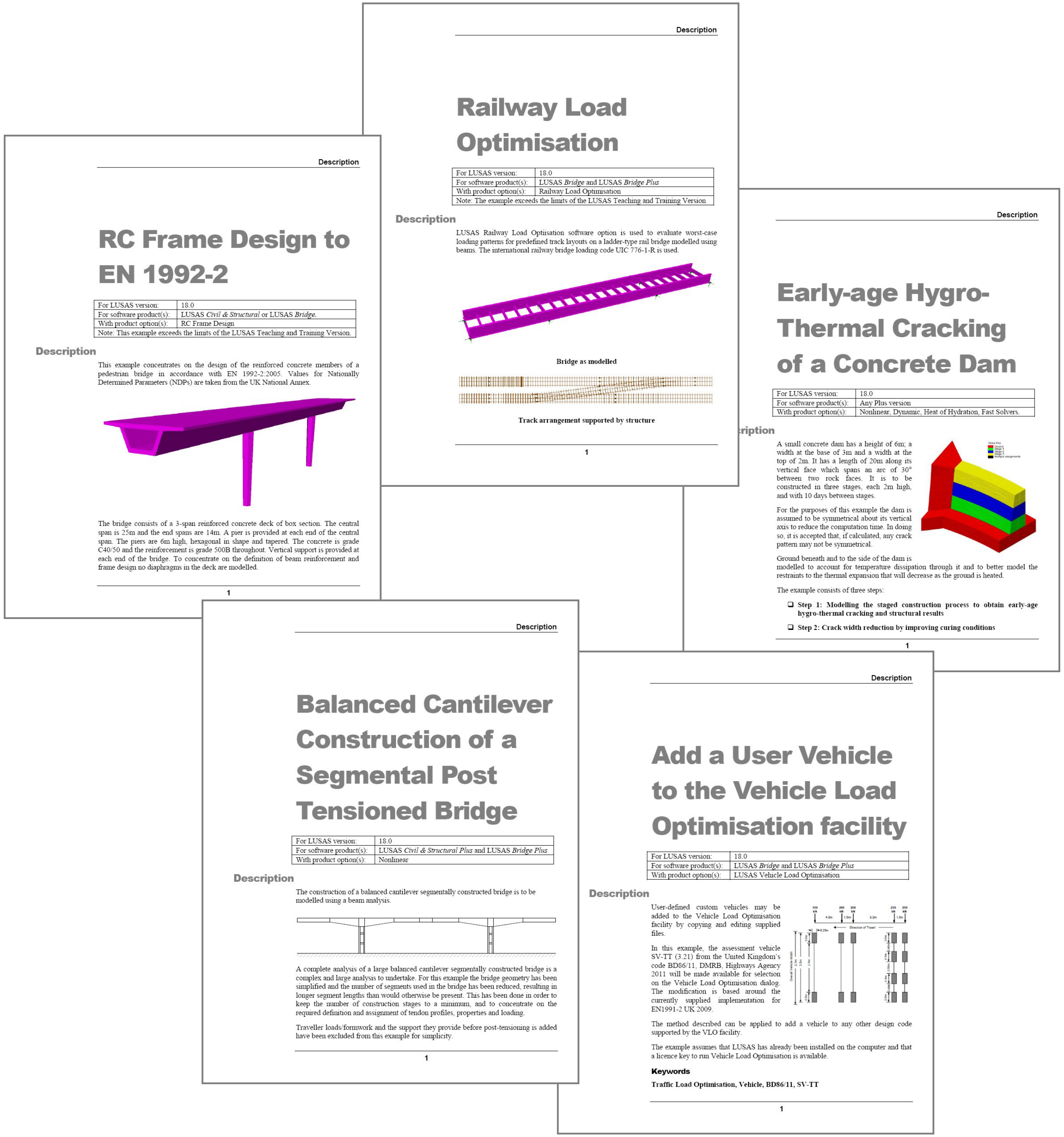
- RC Frame Design to EN 1992-2
- Railway Load Optimisation
- Early-age Hygro-thermal Cracking of a Concrete Dam)
- Balanced Cantilever Construction of a Segmental Post Tensioned Bridge
- Add a User Vehicle to the Vehicle Load Optimisation Facility

Other worked examples

All existing worked examples have been updated to match enhancements made in this version.

Availability

Individual worked examples are provided in PDF format as part of a LUSAS installation, and are also available for download from the LUSAS website.



Design Timeline

Version 18 continues our mission to introduce more and more design code based facilities into LUSAS.

2017 — V16

- Steel frame design
- RC slab /wall design
- Enhanced traffic loading
- Design combinations
- Codified creep and shrinkage
- Time dependent prestress losses
- Response spectra

2018 — V17

- Enhanced steel design
- Restructured prestress
- Enhanced design combinations
- Creep and shrinkage material deformations

2019 — V18

- RC frame design
- Rail load optimisation
- Enhanced steel design
- Concrete cracking / crushing
- Enhanced prestress

TBA — V19

- Parameterised bridge modelling
- Composite deck design
- More steel and RC frame design

... extending your workflow from analysis into design

Summary of all new features and enhancements in LUSAS Version 18

Reinforced concrete frame design

- EN1992-1:2004/2014 and EN1992-2:2005/2014 supported.
- Reinforced concrete compound material.
- Section and line reinforcement utilities.
- Use for regular/arbitrary sections and voided/tapered members.
- Obtain detailed graphical and tabular results and interaction diagrams.

Rail Load Optimisation

- UIC Leaflet 776-1 (5th Edition).
- EN1991-2 Recommended Values.
- EN1991-2 National Annexes for Denmark, Finland, Ireland, Italy, Norway, Poland and United Kingdom.
- NR-GN-CIV-025.

Hygro-thermal analysis

- Model the time (hydration) dependent behaviour of concrete.
- Couple with a structural analysis to determine time- and age-dependent deformations, stresses, crack-widths and more...

Steel frame design

- AASHTO LRFD 8th edition supported.
- AS4100 - axial load checks for equal/unequal angles included.
- EN1993-1-1 / EN 1993-2 - axial load checks for Class 3 angles.
- EN1993-2 now supports Italy and Spain National Annexes.

General improvements

- Post-tensioning facility supports India IRC:112-2011.
- Restart facility supported by LUSAS Modeller.
- Codified concrete creep materials with nonlinear cracking.
- Mohr-Coulomb Friction Interface material.
- Additional design load combinations supported.
- Examine the definition of a combination or envelope.
- Examine computed results for combinations and envelopes.
- Create a loadcase from a smart combination result.
- Faster creation of influences and loadcases when using LUSAS TLO.

Element library

- Hygro-thermal elements.
- Interface element for soil-structure interaction modelling.

New worked examples

- RC frame design to EN1992-2.
- Rail load optimisation.
- Early-age hygro-thermal/structural analysis of a dam.
- Staged construction of a segmental post-tensioned bridge.
- Add a user vehicle to the vehicle load optimisation facility.

For more information visit our microsite at www.lusas-releases.com

LUSAS

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