注：详见“开始-LUSAS 21.0-Online Help”或安装目录"C:\Program Files (x86)\LUSAS210\Programs (x86)\Online_Help\EnglishUS\lusasm.chm" （把左侧目录框拉到最上面）

New Facilities and Improvements in Version 21.0

In summary:

Major new facilities

- Free Cantilever Method (FCM) Wizard
- Pedestrian Moving Load Analysis
- Moving Load Analysis

Reinforced Concrete Slab / Wall Design

- Sandwich model provided for more design codes
- Shear design checks provided for more design codes

Reinforcement

- Easier modelling of reinforcement in 2D and 3D continuum models

Vehicle Load Optimisation

- Direct Method Influence Envelope introduced
- New rationalised placement method
- Whole structure results

Rail Track-Structure Interaction enhancements

- Zero / Reduced Longitudinal Resistance properties introduced

Bridge Deck (Grillage) attributes

- Multicellular and Shear key attributes introduced

Section property calculation

- Tub girders now supported

Staged construction improvements

- Assign material properties to different loadcases
- Deactivation options enhanced
- New reset deformation attribute

Geotechnical

- Non-reflecting / absorbing boundary supports
- Pre-overburden option added
- Ground water solution controls added to Nonlinear dialog
- Two-phase material properties enhanced for partially saturated materials
- Define pore water pressures by phreatic surfaces
- Selected loading dialogs support pore water pressure freedoms
- Mohr-Coulomb Friction interface material enhancements
- New water pressure distribution loading introduced

Nonlinear solution settings

- Various changes to dialogs

General modelling, analysis and results improvements

- Improved display of values, labels and general model annotation
- Beam projected loading (wind loading) introduced
- Beam end releases now include partial fixity
- Dimension lines
- Design reports improved
- Python scripting language supported
- Advanced exothermic property correction factors
- Speedups
- New graphics drivers supported
- Improved rendering of models
- Modification watermarks introduced
- Locking of model during editing
- Other

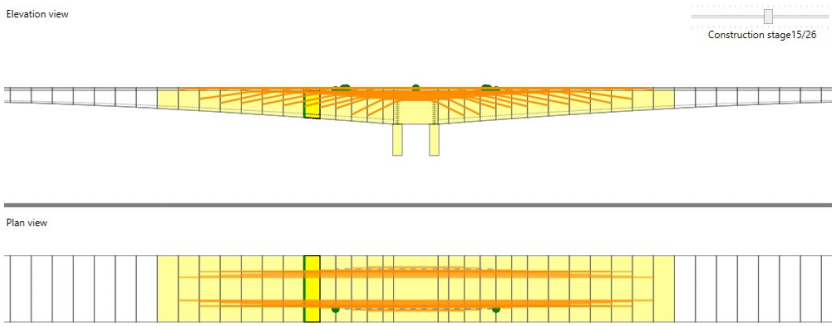
General

- User change requests
- Documentation

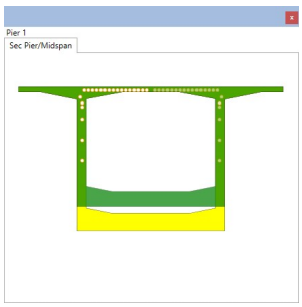
In more detail...

New Free Cantilever Method (FCM) Wizard

The new Free Cantilever Method (FCM) Wizard creates a beam model of a box girder as constructed by the "Free Cantilever Method" (also known as "balanced cantilever construction") from user-defined data. It models the entire construction sequence in order for a step-by-step nonlinear analysis incorporating concrete creep and shrinkage materials (and age attributes) and tendon loading including time-dependent losses to be carried out.

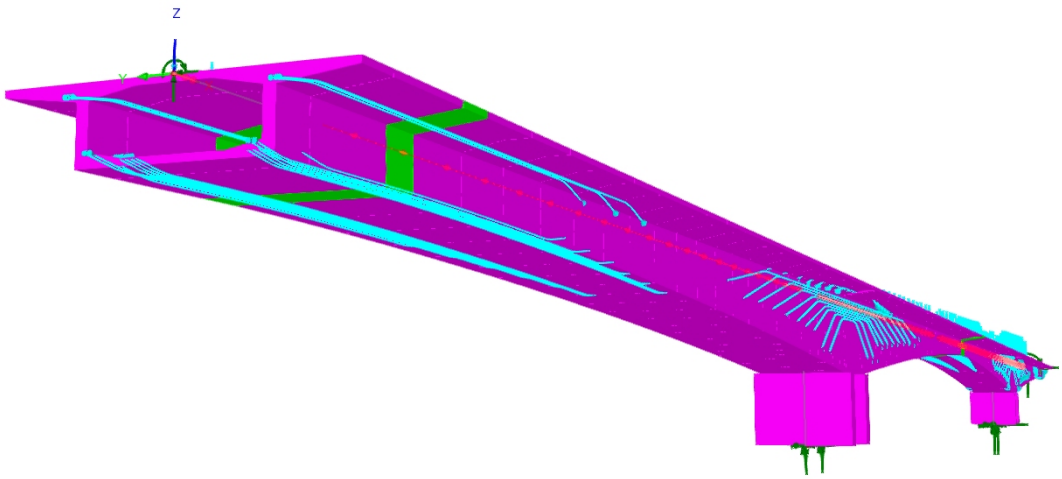


Real-time visualisation of tendons / stages



Section viewer

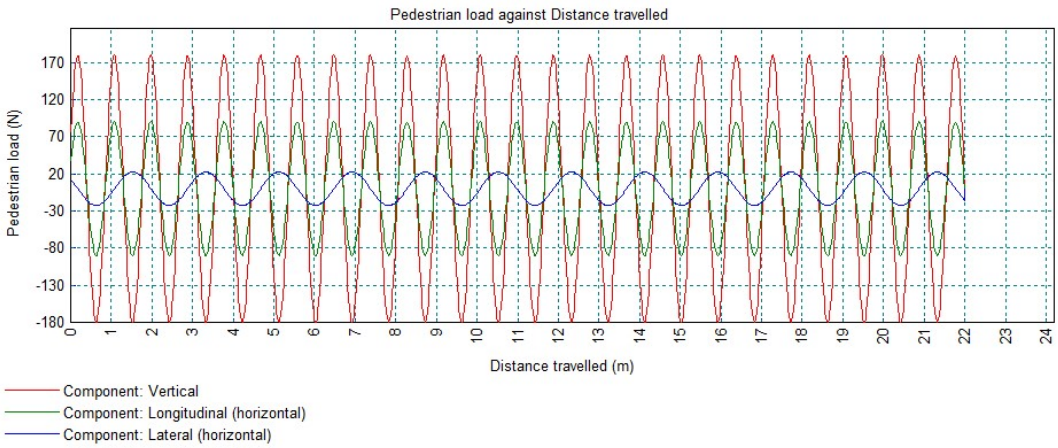
The FCM wizard creates the necessary tendon loading attributes and assigns each to the correct segments at each stage of construction, considerably speeding-up the modelling process. Dynamic visualisation of tendons in the bridge on plan, elevation and within each segment section is provided within the wizard. On solving a model, tendon losses are calculated to a chosen code of practice.



Model as built by the FCM wizard

New Pedestrian Moving Load Analysis

- A new **Pedestrian Moving Load Analysis** facility is available for use with the step-by-step dynamics option. It enables the dynamic effects associated with pedestrians moving across a structure to be modelled in accordance with a chosen design code, creating all the associated loadcases for further evaluation. It requires a **pedestrian load definition** (incorporating vertical pulsating and optional lateral and longitudinal effects) that may be moved at a constant speed, along a reference path, in a forward or reverse direction.
- A **general pedestrian load** may also be defined and used to enter arbitrary constant and sinuisoidal functions, define pedestrian loading for codes not currently supported directly, and to apply the vertical component produced by one code, but with a slightly different pedestrian speed than the one enforced by that code's pedestrian load definition.



Moving Load Analysis

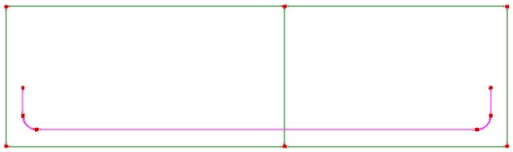
- A new **Moving Load Analysis** facility simplifies modelling of a vehicle load moving along a reference path across a across a model of a bridge or an embankment. A 'Moving Load Analysis' entry is added to the Analyses Treeview, containing a loadcase for each load position, along with maximum and minimum envelope entries containing those loadcases to provide the full effects of the load passing over the structure.

RC Slab/Wall Design

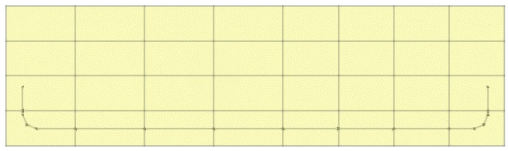
- The **RC Slab / Wall Design** facility carries out comprehensive design checks to more international Codes of Practice. It includes Strength/ULS and SLS checks based on flexural, twisting and in-plane effects, shear, stress limits, minimum and maximum areas of reinforcement and crack widths or spacing considerations as appropriate for all supported codes.
- The use of a sandwich model based upon Annex LL of EN1992-2 (and CEB-FIP Model Code 1990) is now provided for use with **BS 5400-4:1990**, **BS 8007:1987** and **BS 8110-1:1997 and BS8110-2:1985** (UK), **IRS:CBC-1997** (India), **MOMRA Bridge Design** (Saudi Arabia), **NZS 3101-1:2006** and **NZTA Bridge Manual v3.3** (New Zealand), **SABS 0100-1 (Ed. 2.2)** (South Africa) and **SS CP65-1999** (Singapore). This major improvement to the RC Slab/Wall design facility removes most of the limitations of the previously implemented methods (Wood-Armer and Clark-Nielsen) for those codes and extends the applications for which this RC slab / wall design facility can be used.
- For the existing supported design codes, which include those for USA, UK, India, New Zealand, Saudi Arabia, Singapore and South Africa, shear design checks are now included for **BS 5400-4:1990**, **BS 8007:1987** and **BS 8110-1:1997 and BS8110-2:1985** (UK), **IRS:CBC-1997** (India), **MOMRA Bridge Design** (Saudi Arabia), **NZS 3101-1:2006** and **NZTA Bridge Manual v3.3** (New Zealand), **SS CP65-1999** (Singapore) and **SABS 0100-1 (Ed. 2.2)** (South Africa).
- The 'Cope & Clark', 'Iterative Cope & Clark' and 'Ignore Mxy and Nxy' methods of carrying out calculations have been added to the 'General' tab of all supported design codes for when principal axes do not align with reinforcement directions.
- A new option added to the 'General' tab of all design codes that provide a value for the calculation of the cracking stress allows SLS checks to be based conservatively on the assumption that all RC sections are cracked - or less conservatively on the basis that below a specified 'cracking stress' threshold, sections may be assumed uncracked.
- Crack width calculations, for those codes which include them, can now be calculated at the concrete face or at the 'cover required for durability', giving additional control over the design check to avoid over-conservatism.
- Detailed rendered calculations referencing clauses from design codes are available for all checks made for all design codes.
- **See the full list of RC slab / wall design codes now supported.**

Easier modelling of reinforcement in 2D and 3D continuum models

Reinforcement bar arrangements can now be modelled in 2D and 3D continuum models without the need to subdivide the feature geometry to follow the lines of reinforcement, greatly simplifying the modelling process. Lines representing reinforcement bars are assigned **parasitic bar elements** which sit wholly inside host elements. The node and element spacing along the line to which the line mesh attribute is assigned is determined by the intersection of the line and the edges (2D/axisymmetric) or faces (3D) of the host elements through which the line or lines pass. The line mesh created may also be refined using spacing options.



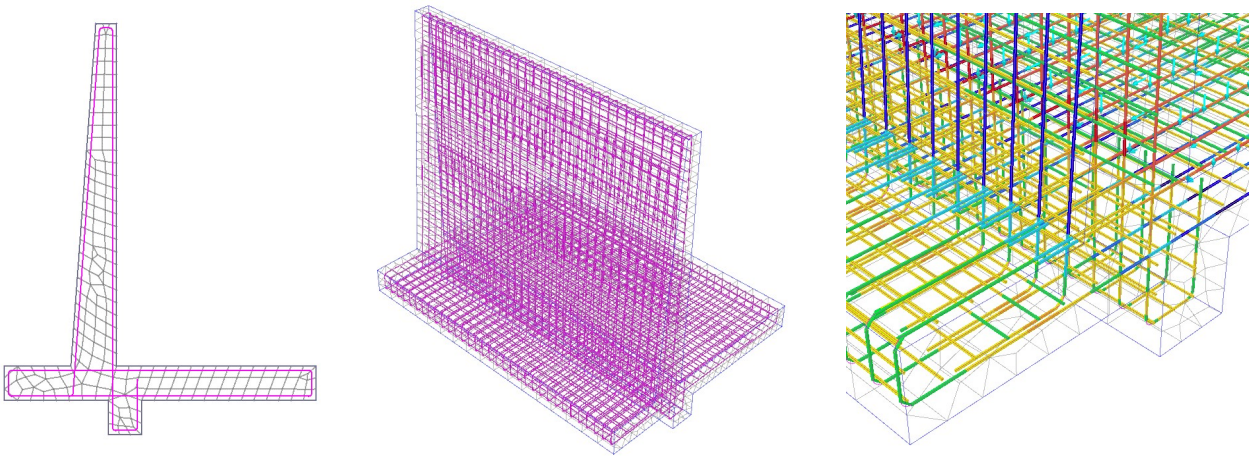
Surfaces representing concrete and lines representing reinforcement bars



Parasitic bar elements created within host elements

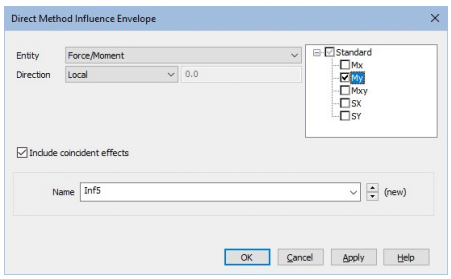
Typical application

In this retaining wall example, individual reinforcement bars are modelled in detail (allowing for lap lengths where appropriate), grouped into a 'set' of bars and copied at a regular spacing along the length of the wall. After solving, stresses in bars can be readily obtained.

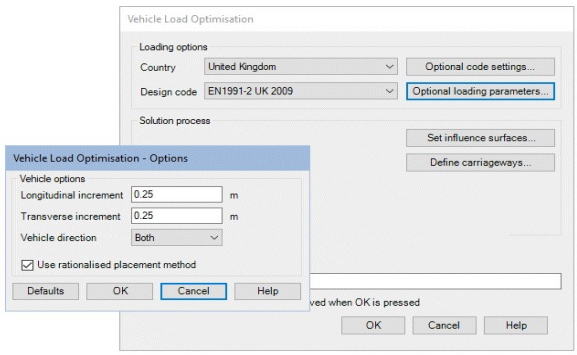


Vehicle Load Optimisation

- A new **Direct Method Influence Envelope** attribute has been introduced. These differ from **Direct Method Influence** attributes in that they allow selection of all the components that are to be optimised (as opposed to only being allowed to only select one in the other Direct Method Influence attribute) and they are assigned to meshed features and not directly to element nodes. When assigned to point, line or surface features in a model they will provide the optimised load effect of interest (e.g. My) at all nodal locations in the assignment. If an option to include the coincident effects is also chosen, all the coincident effects (e.g. Fx, Fy, Fz, Mx, Mz) at all assigned locations will also be provided for each selected results component (as opposed to having to select which ones to include individually). The previous method, in which the VLO facility generates load patterns each in a loadcase of its own, is retained and is useful for checking purposes.

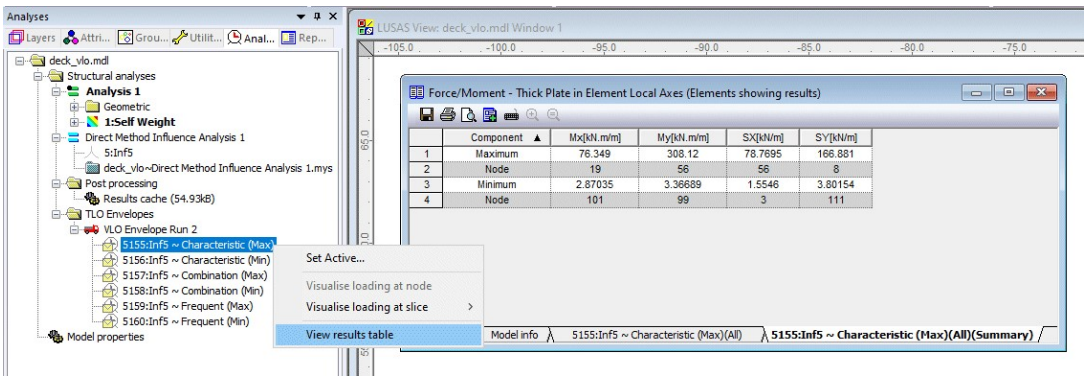


Direct Method Influence Envelope dialog



VLO Optional Loading Parameters dialog

- A new **rationalised placement method** option has been added to the VLO Optional loading and RLO Optional loading parameters dialogs. This considers loading of adverse areas only when placing a vehicle or train traffic load, ignoring the relieving areas. Its use generally provides the most onerous vehicle loading arrangements faster than by considering loading on all loadable areas.
- In the **Vehicle Load Optimisation** facility, traffic load effects can now be obtained for the whole structure and not just selected locations of interest. A new **Vehicle Load Optimisation > VLO Envelope Run** menu item provides a faster alternative to having to use numerous VLO-generated loadcases prior to solving the static analysis and then enveloping those loadcases, as has been required previously. With the new facility a single load envelope is created for each maximum and minimum condition (i.e. for each Strength, Serviceability, Characteristic or Frequent case, according to the selected Code of Practice), for combining with other load cases as required. The envelope is created for each DMIE (Direct Method Influence Envelope) as well.



VLO Envelope Run loadcases and associated printed results

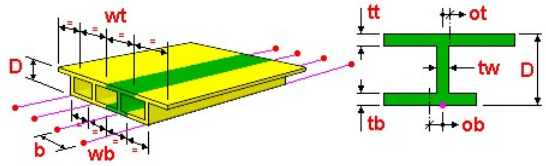
Rail Track-Structure Interaction enhancements

- When carrying out **Rail Track-Structure-Interaction** modelling in LUSAS, Zero Longitudinal Resistance (ZLR) and/or Reduced Longitudinal Resistance (RLR) **properties** and **regions** over which they apply can now be considered. Use of these can help to relieve regions of high axial stress in the tracks.

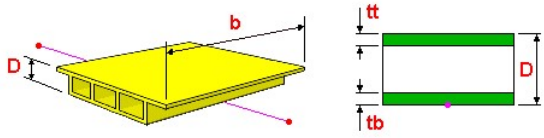
New and updated Bridge Deck (Grillage) attributes

The range of **Bridge Deck (Grillage) geometric attributes** that are used to define the geometric properties of specific bridge decks analysed with reference to, or derived from, grillage formulae published by Hambly and others, has been extended and enhanced. In addition to the existing Slab, Infill Slab, Girder with Top Slab and Transverse Slab with Bracing attributes, options for spaced box beams, multicellular slabs and shear key decks are now provided".

- **Multicellular**

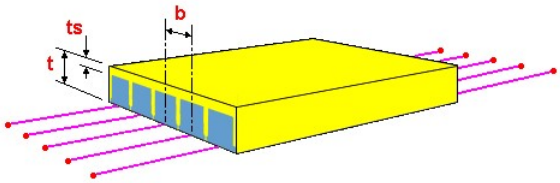


Multicellular (longitudinal beams)

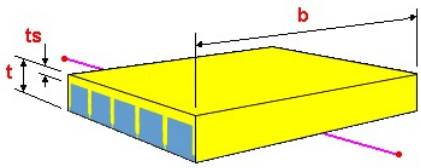


Multicellular (transverse beams)

- **Shear key**

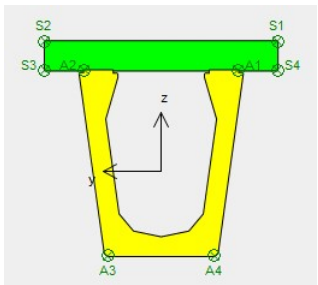


Shear key (longitudinal beams)



Shear key (transverse beams)

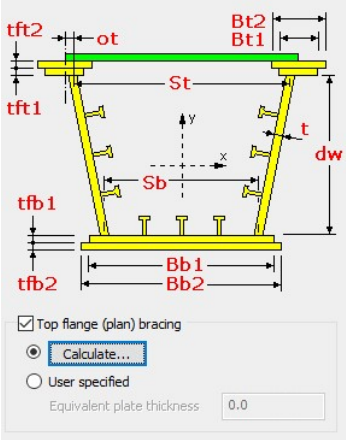
- **Girder and Top slab**



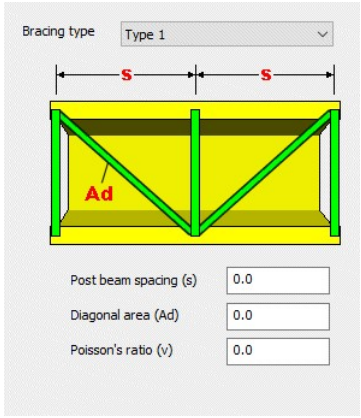
- The '**Girder and Top slab**' bridge deck geometric attribute implemented in Version 20 has been extended to include tub girders and precast U sections. Section types are now selected via a droplist of bridge types, which sets the options available for each beam type on each tab, and determines which formulae are used for the calculation of properties.

Section property calculation

- A tub girder section has been added to the range of **plate girder section property calculators**. Top flange bracing types can also be specified, allowing for easier modelling of bridge decks incorporating these girders.



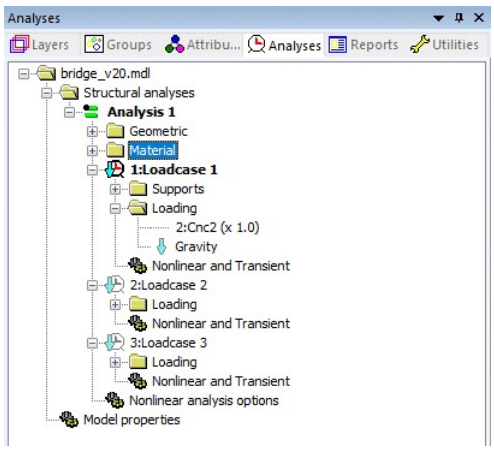
Tub girder section



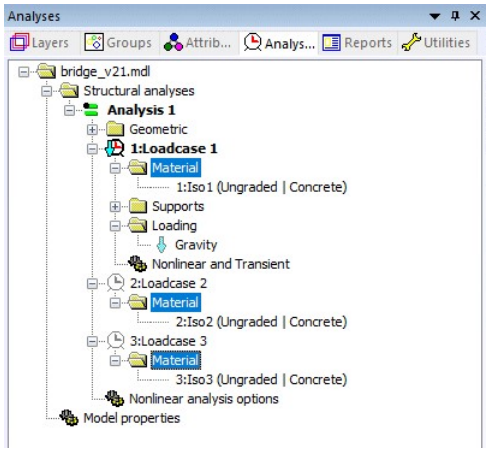
Tub girder top flange (plan) bracing

Staged Construction improvements

- **Material properties** can now be assigned to separate loadcases within a nonlinear analysis, rather than be defined only for a nonlinear analysis as a whole. This allows for easier solving of nonlinear problems with changing material properties. There is no need to assign material to every loadcase, only to the loadcase in which the material changes. When a nonlinear analysis is solved, it will be assumed that the material in a preceding loadcase is unchanged unless overwritten by a new assignment. Assignment of a material now takes place in a similar manner to that for assigning a support, where a feature is selected and an analysis and loadcase are specified. Note that for a linear analysis all material/composite assignments must be made to the first loadcase of the analysis.

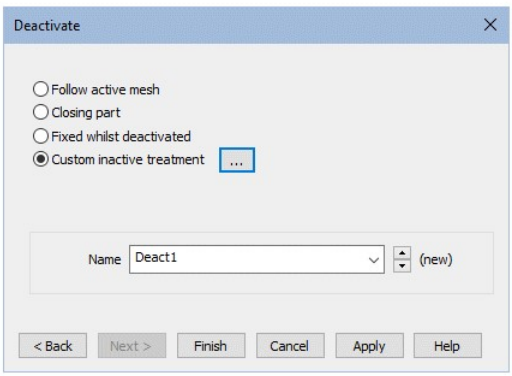


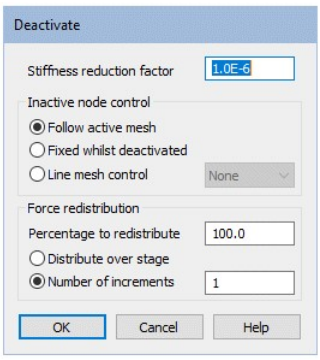
Material folder location prior to Version 21



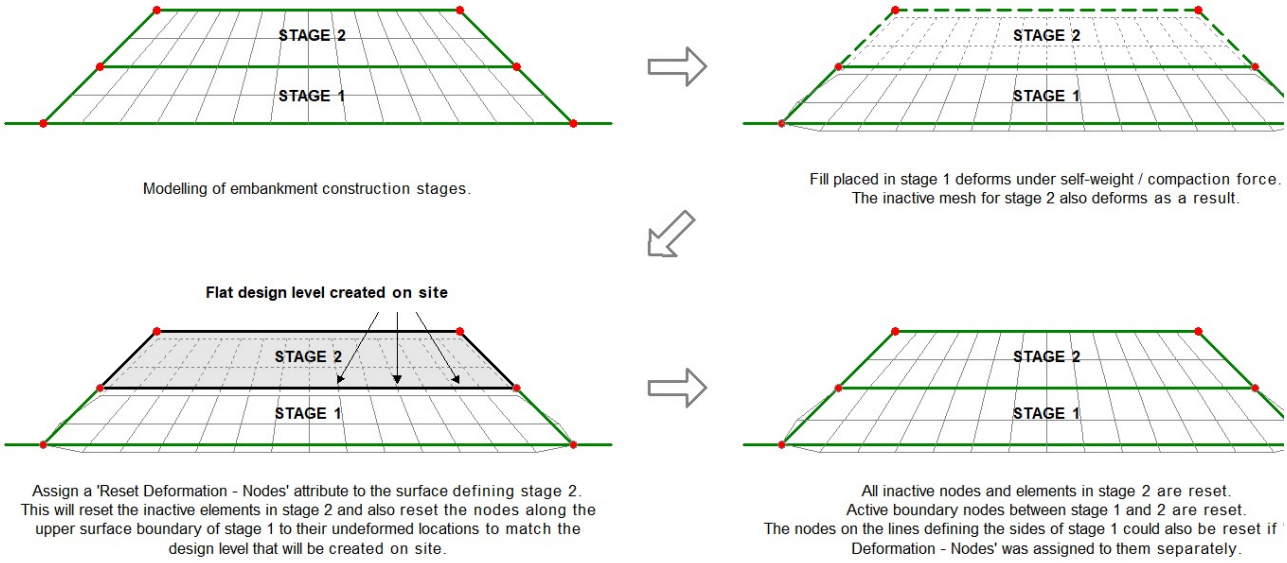
Material folder locations permissible in Version 21

- The **Deactivation** dialog has been updated for ease of use. A new 'Fixed whilst deactivated' option holds nodes in their as-drawn location, being released on activation. This is useful when representing fill material or concrete which is placed on site to an as-drawn level, such as in an embankment model. Deactivation may optionally be gradual over the steps of an automatic nonlinear incrementation, rather than occurring in one step. This assists with convergence when the analysis also involves nonlinear materials or geometric nonlinearity.



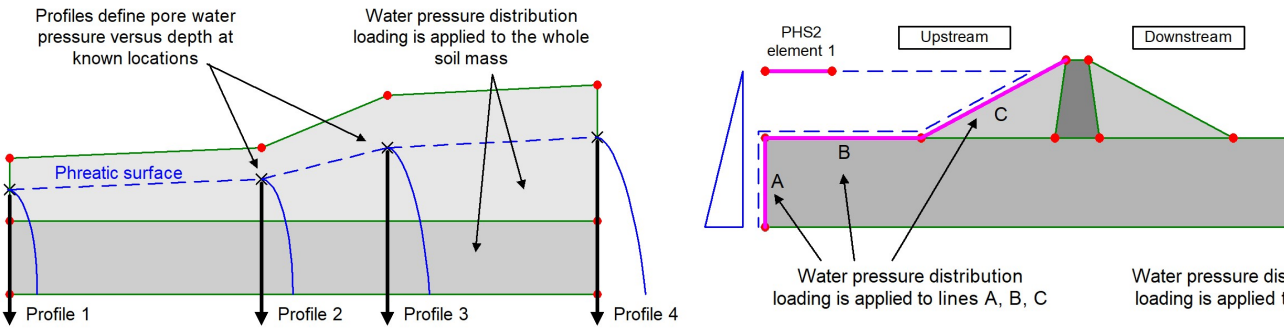


- A new **Reset Deformation** attribute can be assigned to appropriate features in a model in order to reset either node or element locations in order to establish an initial equilibrium or other required state.



Geotechnical enhancements

- **Non-reflecting / absorbing boundary supports** can now be specified with viscous properties that correspond to a continuation of the material at that boundary continuing semi-infinitely beyond the support location.
- POP (Pre-Overburden Pressure) is a new option to specify initial stress state in the **Duncan-Chang** and **Modified Mohr-Coulomb** models.
- Groundwater solution controls have been added to the nonlinear control **Advanced Solution Strategy** dialog.
- New options for drainage/filling curves are included when a partially saturated material is defined. These are: 'Constant water content', 'Valiantzas', 'Van Genuchten-Mualem', 'Brooks-Corey' and 'Piecewise linear'.
- Pore water pressures can now be defined directly, or indirectly by defining **phreatic surfaces** (which represent the position of the free water surface) along with soil properties and boundary conditions.
- Concentrated, face pressure and global distributed loading definition dialogs now allow for the input of pore pressure fluxes (m^3/s for concentrated loads, m/s for others) for elements that support this capability.
- Normal and tangential stiffnesses for the **Mohr-Coulomb Friction Interface** material can be input either as factors (as already available) or as absolute values.
- A new **Water Pressure Distribution** loading attribute is introduced. The pressure profile may be calculated either from a **phreatic surface** or from fully defined profiles that are assigned to the continuum.
- The new **water pressure distribution** loading and **phreatic surface** attributes can be used in various ways to specify or determine pore water pressure throughout the soil block (continuum). See **Specifying / Determining Pore Water Pressure** for more information.



- Geotechnical modelling facilities are only available for licence keys that support that option.

Nonlinear solution settings

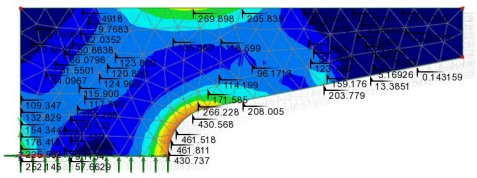
- The **advanced nonlinear incrementation parameters** dialog has been made easier to use and also sees the introduction of a new 'Path direction' option for arc-length control.
- The **nonlinear advanced solution** dialog has been made easier to use and also sees the introduction of a new line search strategy option for iterative acceleration..
- The **advanced time step parameters** dialog of the **Time Domain** panel of the **Nonlinear & Transient** control dialog has been simplified.
- **Arc-length restart parameters** have been moved from the Advanced Nonlinear Incrementation Parameters dialog to the Initial State tab of the Analysis dialog.

General modelling, analysis and results improvements

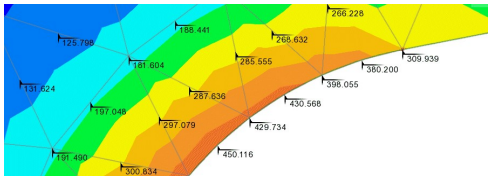
Improved display of values, labels and general model annotation

- Results values on the Values and Diagrams layers and text labels and annotation are now, by default, only displayed if they do not clash with other values, labels or text visible in the model view window. In situations where clashes occur, higher results values take priority over lower ones and larger negative values take priority over lesser ones, with clashing values or text made transparent, providing clearer displays.
- Values are now displayed with a location symbol to show where they relate to on a model.

- Enlarging the view of a model will progressively make previously clashing text visible.



Values plot showing only main values



Enlarged view showing all values

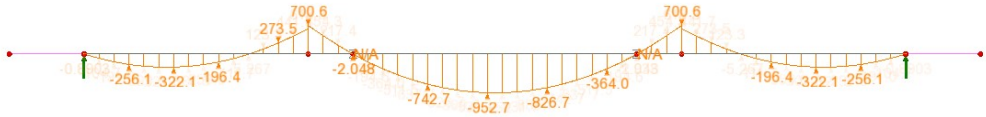
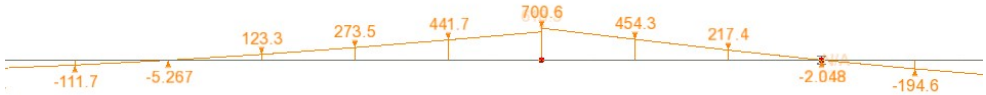


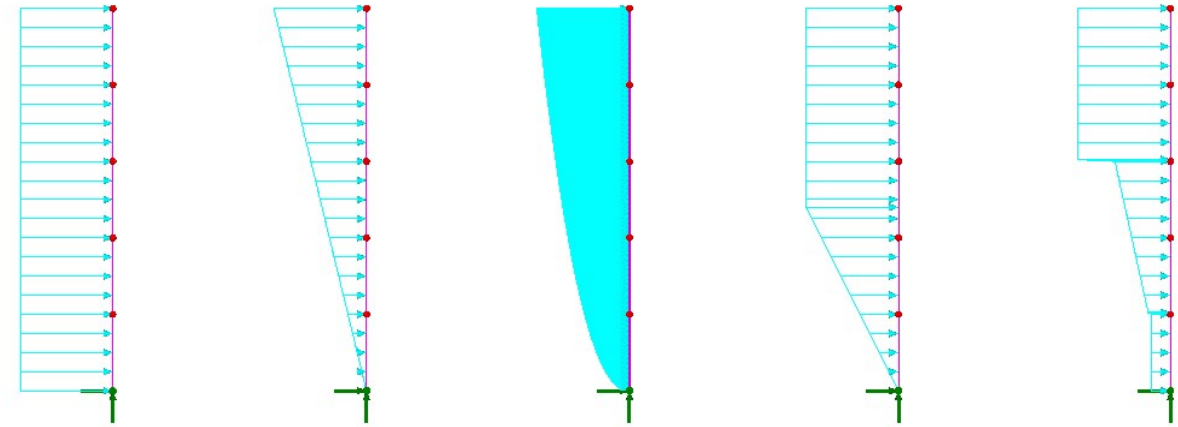
Diagram plot showing only main values



Enlarged view showing all values

Beam projected loading (wind)

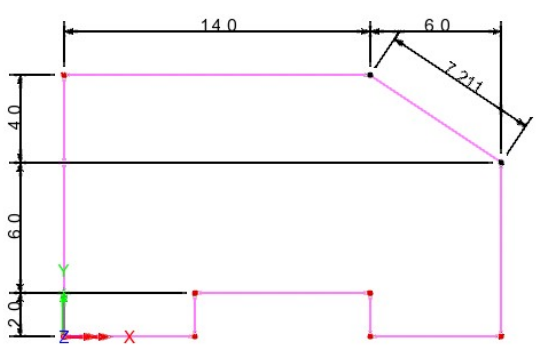
- A new loading attribute '**Beam Projected Loading (Wind)**' has been introduced allowing you to assign a pressure loading to line beam members to model wind loading. It can accommodate complex variations of pressure with height or other variables. Loading is evaluated on each member to which it is assigned on the basis of the area (i.e. the length x section width) that member presents in the plane perpendicular to the pressure loading.



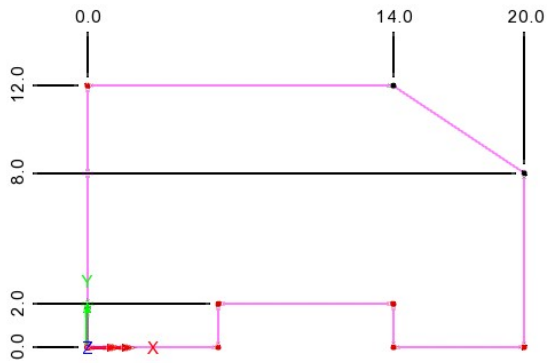
Constant Linear Parabolic Stepped with cut-offs Profile variation

Dimension lines

- A new **Dimension Lines** attribute has been introduced, providing 'distance' dimensions aligned to global directions or aligned to the member (to give the 'true' length), and 'ordinates' as an alternative. Colours, fonts, arrowheads, decimal places and units may be controlled for each view window in the Attributes layer of the Layers treeview.



Distance dimension types



Ordinate dimension types

Beam end releases now include partial fixity

- **Partial fixity** of the ends of a member represented as a line or a combined line may be specified for a chosen freedom as either a factor or a spring stiffness value.

Design reports improved

LUSAS design reports, which show design calculations with clause references have been improved:

- Reporting facilities have been made more consistent across the range of LUSAS design facilities (RC Slab / Wall Design, RC Frame Design, Composite Deck Design, Steel Frame Design etc). Any selected rendered design checks may be added to a LUSAS report, and all the rendered design check reports may be printed consistently.
- Reports can now be searched for particular text and one or all of the rendered design check reports within the currently open dialog may be saved in searchable PDF format.
- Interactive rendering checks are now carried out concurrently.
- Formatting of long equations has been improved. For example. if an equation 'stack' will fit into a page width they are shown with any equals signs aligned in case of a multiline equation, and if an equation does not fit the page, it will be split at appropriate locations into a multiline entry.

Axial force in the direction of the principal shear

$$N = N_x \cdot \cos^2(\varphi_0) + N_y \cdot \sin^2(\varphi_0) + 2 \cdot N_{xy} \cdot \sin(\varphi_0) \cdot \cos(\varphi_0)$$
$$= 0 \cdot \cos^2((-28.0481)) + 0 \cdot \sin^2((-28.0481)) + 2 \cdot 0 \cdot \sin((-28.0481)) \cdot \cos((-28.0481)) = \mathbf{0\ N}$$

Moment in the direction of the principal shear

$$M = M_x \cdot \cos^2(\varphi_0) + M_y \cdot \sin^2(\varphi_0) + 2 \cdot M_{xy} \cdot \sin(\varphi_0) \cdot \cos(\varphi_0) + M_0 \cdot \sin(\varphi_0)$$
$$= (-35.5134E6) \cdot \cos^2((-28.0481)) + (-50.2045E6) \cdot \sin^2((-28.0481)) + 2 \cdot 30.7145E3 \cdot \sin((-28.0481)) \cdot \cos((-28.0481)) + 124.321E3 \cdot \sin((-28.0481)) = \mathbf{-38.7871E6\ Nmm}$$

Improved equation formatting in LUSAS design reports

Concrete modelling

- For concrete heat of hydration modelling, **advanced exothermic property** "correction factors" have been added to an Advanced dialog. These make it possible to adjust specific entries to better match experimental results.

Python scripting language supported

- Session files and other script files in Modeller can now be optionally written out in Python as an alternative to VBScript. Modeller already executes Python scripts or commands entered in the LPI command bar, and so this makes it easier to create such scripts. This requires Python and 'Python for Win32 (pywin32) extensions (2022)' to be independently installed. See **Modeller Settings** in the LUSAS Configuration Utility for more details.

Speedups

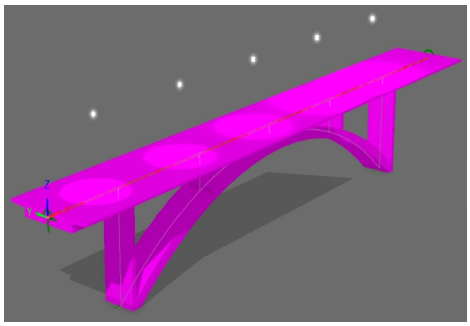
- Results are now assembled faster when viewing contours, values, diagrams, Print Results Wizard output and similar.
- The Vehicle Load Optimisation and Rail Load Optimisation facilities now rapidly produce envelopes of traffic loading effects over sections or the whole of the model (without producing many loadcases) and use a rationalised method to generate these results - or load patterns, if selected - more rapidly.
- Results processing of both IMD loadcases of element results that utilise the 'Spectral' results option with the 'CQC Combination' spectral response type and IMD loadcases of element results for large models is now substantially faster.
- The time taken to draw fleshed members and contours has been greatly reduced and memory demands have been lowered, enabling the creation of much larger, more detailed beam models when using standard sections.
- The rendering of selected members within the model view has been optimised, leading to significantly faster response times for interactive selection in large models.
- The 'Combination and envelope settings' object in the Analyses Treeview has been replaced with a new object named '**Results cache**'. The results cache item provides continuous feedback, within its name, of the amount of disk space currently used by the cache. Caching of results is now turned on by default and will make second and subsequent requests of results faster.
- **Auto renumbering** of Nodes and Elements, and Point, Line, Surface and Volume geometry is now set 'off' by default. If models created in previous versions have it turned on, Modeller's performance for larger models can be improved by turning it off.
- Locking of a model during editing enables interactive work with larger models to be speedier.
- Some mesh checks that have been found to be unnecessary are switched off by default but can be enabled from the Advanced Meshing Parameters dialog.

New graphic drivers supported

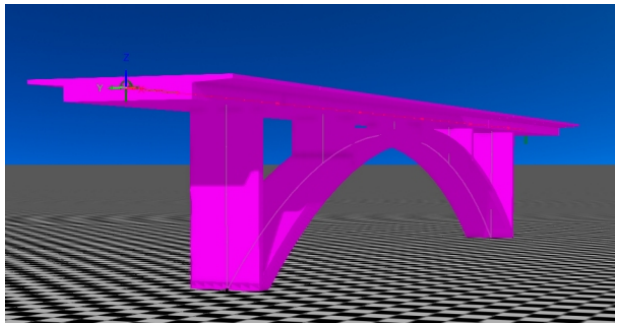
- LUSAS now offers more rendering options, including DirectX, to support a wider variety of modern graphics cards, providing a most robust interface, especially on machines where up-to-date graphics drivers are not always available.

Improved rendering of models

- Model visualisation has been improved with the addition of new **model view illumination** options. These include global lighting, which broadly mimics sunlight, and point lighting, which mimics isolated sources of light such as streetlamps. For global lighting the location and direction of the incoming global light, its movement in relation with the eye position of the scene, its magnitude and colour, and whether ambient occlusion should be applied can be defined. For local lighting each light source's position, colour, brightness, and whether ray marched shadows are applied can be stated.
- **Model view backgrounds and ground planes** are now supported. View backgrounds can be a solid colour, a static image loaded from disk, or a chosen predefined skybox that comprises a set of 6 images that form the top, bottom and four sides of a cube that encompasses the view of a model to give the illusion of a vast, open 3D background. Ground planes help to visually locate or 'ground' a model in 3D space and include 'Graph paper', 'Chessboard' and 'Solid colour' options and a range of 'texture' styles.



Local lights defined in addition to global lighting on a solid colour ground plane



Perspective view with a chessboard ground plane and skybox

Modification watermarks and visual reminders when results are out of date

- A "Modification Mode" watermark will now appear in the upper half of a model view window when the model has been modified more recently than solved. In addition a "Results are out of date" watermark is displayed in the lower half of a model view window to emphasise this point.
- When viewing **Print Results Wizard** output, for a report or a graph that was created with 'out of date' results, a message stating that the values are 'out of date' is printed above the data. These measures are intended to ensure that users are aware that the viewed or printed results are not those that would necessarily be obtained if the model was solved again.
- If a model is loaded into Modeller and an associated results file from Solver is found to be 'out of date', you will no longer be asked if you want these results to be loaded, and instead will have to load them manually - saving time waiting for out of date results to load.

These notifications and changes will allow you to continue to view results while altering a model, and also ensure that you are reminded of the need for the model to be re-solved to obtain updated results.

Locking of model during editing

- A new menu item **Tools > Mesh > Attribute Evaluation Lock** has been added to prevent LUSAS Modeller from evaluating the effect of any change (creation, modification, assignment) to most attributes. This is similar to locking any evaluation of changes made to the mesh using the 'Mesh lock' menu item and can be used to work faster with larger models.
- The existing Mesh lock button has been modified to become a drop menu, with the new Attribute Evaluation Lock option added to it.
- When the Mesh layer is being displayed and the Mesh Lock is 'on', the Mesh layer image (for all views) now changes to include a padlock to show that the effect of any changes made will not be seen on the model until the lock is turned 'off'.
- When the Attributes layer is being displayed and the Attribute Evaluation Lock is 'on', the Attributes layer image (for all views) will change to include a padlock to show that the effect of any changes made to any attributes or their assignments will not be seen on the model until the lock is turned 'off'.

Other enhancements

- The ability to define **beam end releases** has been extended to include partial fixity. A spring stiffness may be either specified directly or a fixity factor used.
- From Version 21 onwards, surfaces created in a 2D analysis ((inplane, axisymmetric and grillage) are automatically reversed if necessary, so that the surface normal aligns to the global Z axis. Existing models and scripts are not affected by this change. The existing surface reverse command is unaffected, so it is still possible to manually control the surface normal in all analysis types. If the analysis category is changed from 2D to 3D or vice versa the surface normals do not change.
- A number of mesh checking parameters have been added to the **Advanced Meshing Parameters** dialog.
- References to "master" and "slave" in situations where both normally appear together (such as slidelines) have been renamed to be "primary" and "secondary". Any other references to "master", which denotes a controlling feature or capability without a subservient one, have been retained.

User change requests

The originators of all requested changes to the software that have been incorporated in this release will be notified individually.

Documentation

User manuals

All online and printable documentation has been updated for this new release.

Selected manuals are provided in PDF format as part of the LUSAS installation and are also available for download from the LUSAS website.

Worked Examples

Worked examples (in PDF format) and associated files referenced by those examples are available for download from the User Area of the LUSAS website.

New facilities and improvements in the last released version

See **New features and improvements in LUSAS version 20.0**