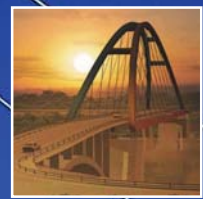


LUSAS
Bridge



Bridge analysis, design and assessment software



LUSAS

LUSAS is the trading name of Finite Element Analysis Ltd - a UK-based company that specialises in the development and marketing of high quality, specialist engineering analysis software. Our range of software products, based on the LUSAS finite element system, provide accurate and reliable solutions for all types of linear and nonlinear stress, dynamic, and thermal / field analysis problems. LUSAS users are provided with a first class technical support service and our Engineering Consultancy division offers specialist finite element consultancy services to all branches of the engineering industry.

For structural engineering analysis and design we provide the following software application products:



for all aspects of bridge engineering analysis, design, and assessment.



for building, civil, structural, nuclear and offshore engineering.



for the design of FRP or structural composites

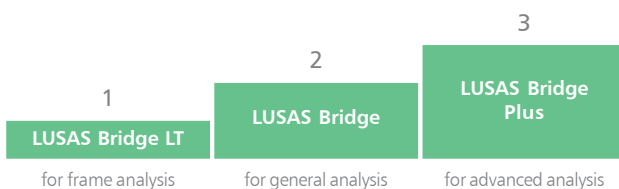


for teaching and research at educational establishments

Note that selected LUSAS Bridge and LUSAS Civil & Structural products include geotechnical and soil-structure interaction capabilities.

LUSAS Bridge software products

LUSAS Bridge software is available in a choice of software levels to suit your needs: Bridge LT, Bridge, and Bridge Plus.



- Use Bridge LT for linear static analysis of structural frames and grillages.
- Use Bridge for linear static and linear modal dynamic analysis of shell and solid models.
- Use Bridge Plus for more advanced analyses using the appropriate purchased option(s).

Element set	Bridge LT	Bridge	Bridge Plus
2D/3D line elements (bars, beams...)	●	●	●
2D/3D surface and volume elements		●	●
Advanced high-performance elements			●

● Element set is included in this software product.

Software options

Extend the capabilities of particular LUSAS Bridge software products by purchasing software options.

LUSAS software options	Software product		
	Bridge LT	Bridge	Bridge Plus
Fast Solvers	●	●	●
Vehicle Load Optimisation	●	●	●
Steel Frame Design	○	○	○
RC Frame Design	○	○	○
Steel and Composite Deck Designer	○	○	○
IMDplus Analysis	n/a	○	○
Nonlinear Analysis	n/a	n/a	○
Dynamic Analysis	n/a	n/a	○
Thermal/Field Analysis	n/a	n/a	○
Heat of Hydration Analysis	n/a	n/a	○
Rail Track Analysis	n/a	n/a	○

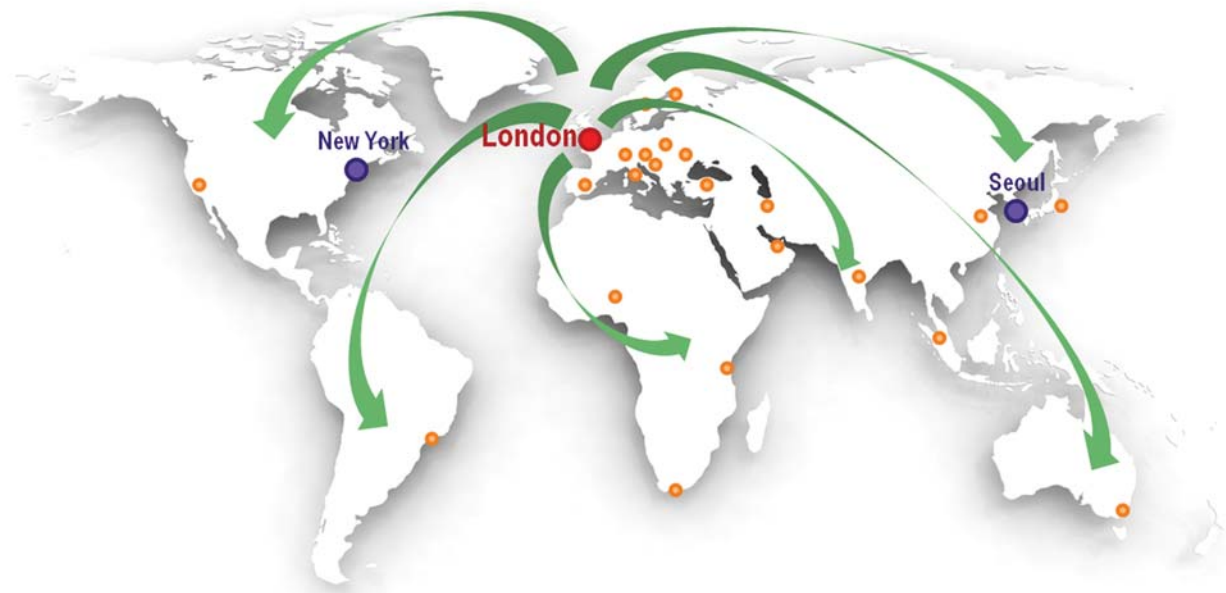
● = Software option is included in this software product for new sales.
 ○ = Software option must be purchased for use with this software product.
 n/a = Software option not available for use with this software product.



Global coverage, users and support

LUSAS software is marketed and supported globally by LUSAS and also through a network of distributors and resellers that cover every continent.

Used by thousands of users, LUSAS is highly regarded in the civil, structural and bridge engineering industries, as demonstrated by an impressive list of clients, which include many of the top international consultancies. LUSAS is also used extensively by government agencies, local authorities and smaller to medium-size consultants, many of whom find that the advanced analysis facilities not only expand their capabilities but also give them a competitive edge. Universities and research institutions use the academic version of LUSAS, which provides a steady supply of proficient LUSAS users to support your use of the software in your industry.



Some typical user quotes

"The technical support I received on my enquiry (and the ones that followed on the same model) was excellent - beyond all expectations!"

"I was impressed with the LUSAS help desk. The responses I received were very detailed, informative and helpful. The support provided really assisted me with a modelling process that I hadn't done before."

"The help provided to me was perfect, thanks very much. Good support as usual from LUSAS."



LUSAS Bridge

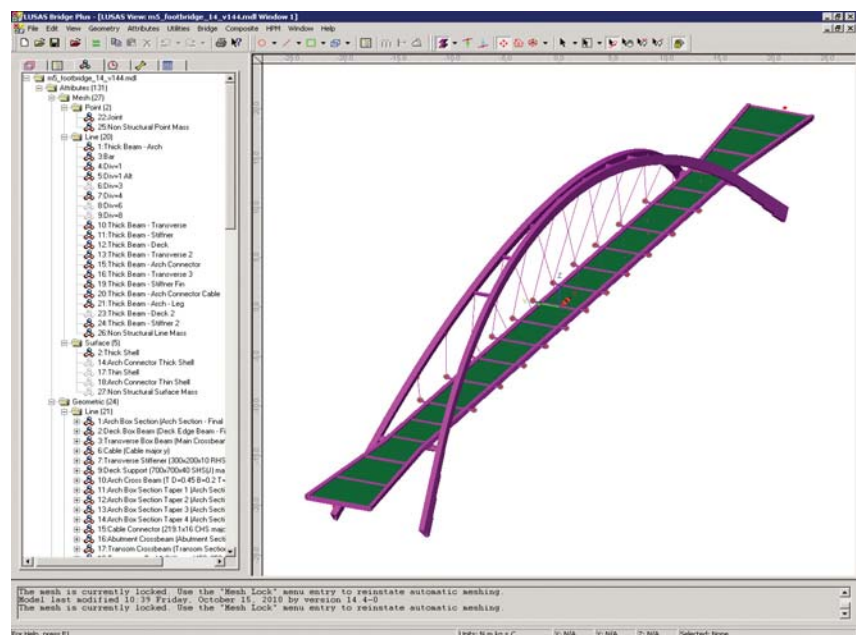
LUSAS Bridge is a world-leading finite element analysis software application for the analysis, design and assessment of all types of bridge structures. Whether you need to carry out a straightforward linear static analysis of a single span road bridge, a dynamic analysis of a slender ‘architectural’ steel footbridge, or a detailed geometrically nonlinear staged erection analysis of a major cable stayed structure involving concrete creep and shrinkage, LUSAS Bridge provides all the facilities you need.

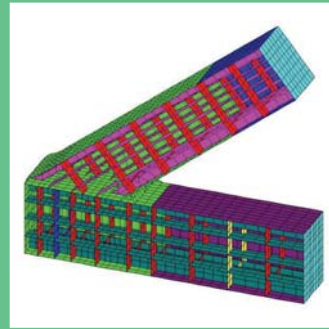
LUSAS Bridge is available in a choice of software levels. Each uses the same Windows user interface, and has modelling wizards, comprehensive vehicle loading and Smart Combination facilities for easy and rapid model generation, load application and combining of loadcase results. Extensive results processing, viewing and report generation facilities give you ultimate control over what you plot and print from your analysis. In short, LUSAS Bridge software handles simple grid/grillage and slab structures with ease and has a full range of additional software options and features for more advanced bridge structures.

- For all bridge types:**
- Slab decks
 - Slab / beam decks
 - Composite decks
 - Straight or curved plate girders
 - Masonry arches
 - Integral bridges
 - Truss bridges
 - Ribbon bridges
 - Movable bridges
 - Cable stayed bridges
 - Suspension bridges
- Used for:**
- Innovative new design
 - Cost-saving re-design
 - Load rating and assessments
 - When design codes can't be used
 - Development of retrofit solutions
 - Erection / demolition engineering

Why use LUSAS Bridge?

LUSAS Bridge provides cost-effective structural modelling and analysis (including soil-structure interaction) of any structure, in one software package. Global and local modelling is feature-based and allows mixing of element types in the same model. Advanced nonlinear geometry, material and contact modelling is a key strength, and the software can also be customised using the LUSAS Programmable Interface. Overall, LUSAS is a trusted provider to industry leaders, and LUSAS Technical Support is stated, by its users, to be simply: “The best in the business.”





Modelling in general

LUSAS Bridge has an easy to use, associative Modeller for modelling / results processing and a fully integrated Solver which can be used independently.

- The user interface is a full native Windows implementation providing an Open Interface to ActiveX compliant Windows software such as Excel, Access, Word and other software.

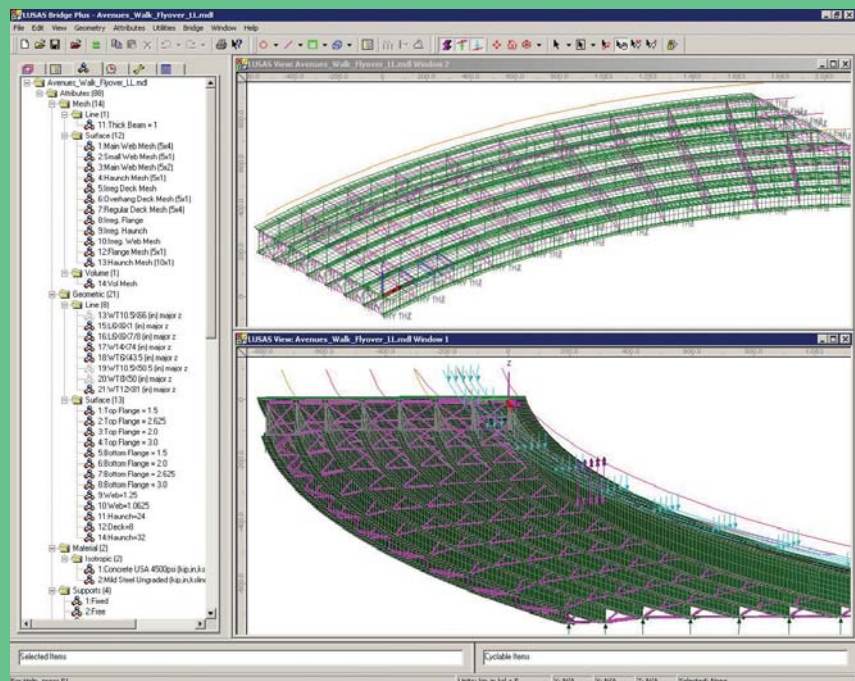
- Customisation of menus, toolbars and dialogs plus the ability to create your own wizards with Visual Basic Scripting provides limitless potential to tailor the software to specific needs.

- Models are formed of layers where the visibility and properties of each layer can be controlled and accessed via the layer name held in a Layer treeview, one of a number of treeviews used to organise and access model data.

- Models are created using feature-based geometry methods (points, lines, surfaces and volumes). CAD import / export is also supported. Model features may be grouped together to aid with manipulation, or with the assignment of attribute data.

- Model attributes such as thickness, material, loading etc. can be named explicitly. Once defined, they appear in an attributes treeview ready to be assigned to selected geometry of the model using the "drag and drop" technique.

- Automatic meshing with an easy-to-use mesh refinement capability.



- Built-in associativity, a key feature of the LUSAS Modeller, ensures that if the model geometry is amended, all assigned loadings, supports, assigned mesh and other attributes are automatically updated to suit.

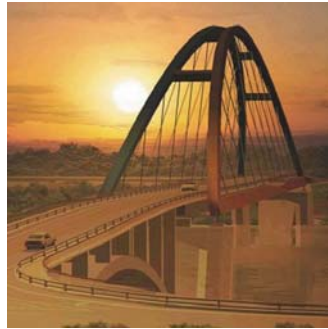
- Fleshing (the visualisation of assigned thicknesses or section shapes) helps to ensure that the thicknesses and eccentricities of slabs and the orientation of beam members are correctly defined.

- Datatips reveal useful model information such as input units expected on dialogs, or assigned properties when the cursor is positioned over a geometry feature.

- The OpenGL implementation provides fast graphical displays. Multiple graphical windows allow simultaneous displays of different parts of the model at different orientations. Powerful cursor selection options and pan, zoom, dynamic rotation and pre-defined views allow for easy viewing and editing of your model.

- A multi-level undo/redo facility allows quick modelling corrections to be made.

- Detailed on-line dialog help links to additional reference manual material to provide you with the most appropriate level of assistance at all times.



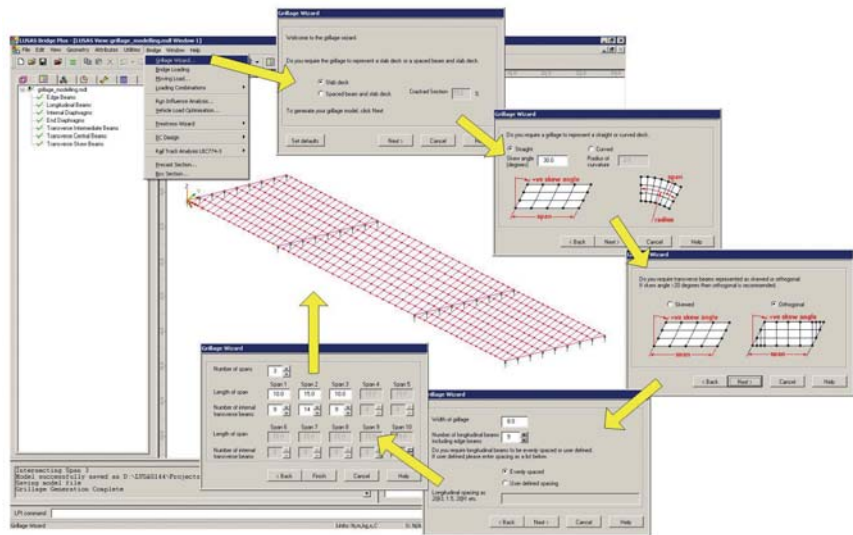
Wizards, libraries and utilities

The use of wizards allows for rapid modelling, generation of loading conditions, and viewing of results. Section libraries and a range of section property calculators provide for straightforward modelling of grid/grillage and beam models.

- A grillage wizard enables the rapid generation of a wide variety of orthogonal, skewed and curved multi-span grillage arrangements. Cracked sections can also be included.

- Wizards for the calculation of critical road and rail loading configurations, design combinations, and dynamic pedestrian loading are available, along with a loadcase generator for moving vehicle and train loads across a model.

- Animation, graphing and print results wizards take users through the steps required to select and display results.



Section libraries and calculators

- Steel section libraries include those for the United States of America, United Kingdom, Eurocode, China, Korea, Canada, Australia and others.

- Common standard section shapes such as rectangular, circular, I-shape, T-shape, L-shape, C-shape and Z-shape sections are easily user-defined.

- A precast beam section generator calculates section properties of a range of country and region-specific precast concrete beams.

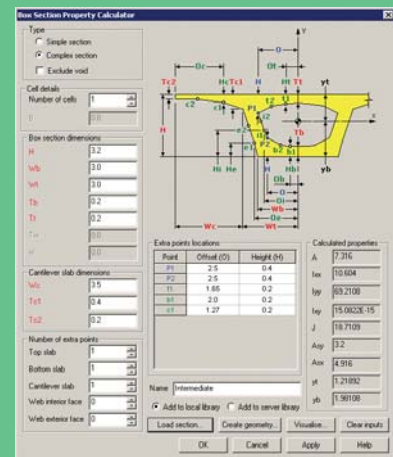
- Section property data for any drawn shape or collection of section shapes can be calculated using an arbitrary section property calculator.

- Section properties of simple or complex, single or multiple box cross sections (with / without voids) can be calculated from entered values.

- Tapering beams can be easily defined by specifying section properties for each end.

- Multiple varying sections are defined along a path of lines allowing straightforward building of models for bridges having curved soffits, or for arch structures having varying cross-sectional thicknesses.

- A library browser permits transfer of attribute data, such as mesh, geometric, material, etc., between models.





Advanced elements, materials and solvers

Unrivalled state-of-the-art linear and quadratic element libraries; advanced material models; linear, nonlinear and seismic isolator joint models; direct and eigen solvers, and a fast solver option collectively allow all types of bridge engineering problem to be modelled and solved as efficiently as possible.

Advanced element libraries

- Plate and shell elements for slab decks
- Beams and shells for prestressed concrete, steel and composite construction
- Solid elements for detailed modelling and studying local effects
- Elements for cabled stayed and suspension structures
- Joint elements for linear and nonlinear joint models

Advanced general material models

- Isotropic including plastic, creep, damage, shrinkage, viscous, two-phase
- Orthotropic including plastic, creep, damage, shrinkage, viscous, two-phase
- Anisotropic and rigidity models
- Temperature dependent models
- Tension only/compression only bar material model
- Concrete models with opening and closing of cracks, concrete crushing, and strain softening based on fracture energy in 2D/3D
- Concrete creep and shrinkage to CEB-FIP Model Code 1990, Eurocode 2, and creep only for Chinese codes
- Geotechnical models including Modified Cam-clay, Mohr Coulomb, volumetric deformation soil model (includes consolidation)
- User-defined models and others

Joint material models

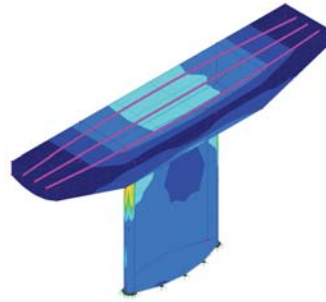
These are used with joint elements to fully define the properties for linear, nonlinear and seismic isolator joints.

- Linear joint models include those for spring stiffness only and for general joint properties having spring stiffness, mass, coefficient of linear expansion and damping factor. User-defined force/displacement and axial force dependent curves are supported.
- Nonlinear joint models include elasto-plastic uniform tension and compression with isotropic hardening, elasto-plastic general with isotropic hardening, smooth contact, frictional contact, a range of hysteretic joints, and user-defined joint models.
- Seismic isolator joint models include viscous dampers (Kelvin and Four Parameter Solid), lead rubber bearings with plastic yield and biaxial hysteretic behaviour, friction pendulum system with pressure and velocity dependent friction coefficient and biaxial hysteretic behaviour, and more.

Fast solvers

A Fast Solvers option (provided with all new sales) provides a range of state-of-the-art solvers for use with all LUSAS Bridge software products.





Load types and combinations

LUSAS Bridge provides a comprehensive range of general loading types to cater for most circumstances. Vehicle load types, train loading, and prestress and post tensioning to many international design codes are also provided. Vehicle load optimisation facilities help find onerous traffic patterns. Envelopes, basic and smart load combination facilities help investigate maximum and minimum primary and coincident effects.

General load types

Structural, prescribed and thermal loads are feature based loads that are assigned to the model geometry and are effective over the whole of the feature to which they are assigned.

- Structural loadings include gravity, concentrated, distributed, face, temperature, stress/strain, and beam loads.
- Prescribed loading options allow initial displacements, velocity or acceleration to be specified.
- Discrete loads distribute a loading pattern over full or partial areas of the model independent of the model geometry.
- Compound loads (as used to define load trains) can be formed from a set of previously defined discrete loads and be assigned to a model as one loading.
- Thermal loads describe the temperature or heat input for a thermal analysis or for a coupled structural / thermal analysis.
- Variations in loading can be applied to all feature load types according to the feature on which they have been assigned.



Prestress and post tensioning

Prestress / Post-tensioning in LUSAS is suitable for beams, slabs and volumes, and incorporates time-stage with creep and shrinkage.

- Computation of tendon forces can be carried out in accordance with various regional codes including AASHTO, Eurocode, and China.
- LUSAS calculates losses appropriate to the age of the concrete and the magnitude and duration of prestress and other loading at any selected time typically at each stage, and at the end of the service life of the structure.
- For design codes that support time-dependent loss calculations, adjustment of losses to account for prior losses are also calculated.
- Span-by-span, progressive placement (segmental), balanced cantilever and incremental launching time staged construction methods are supported.



Vehicle Loading

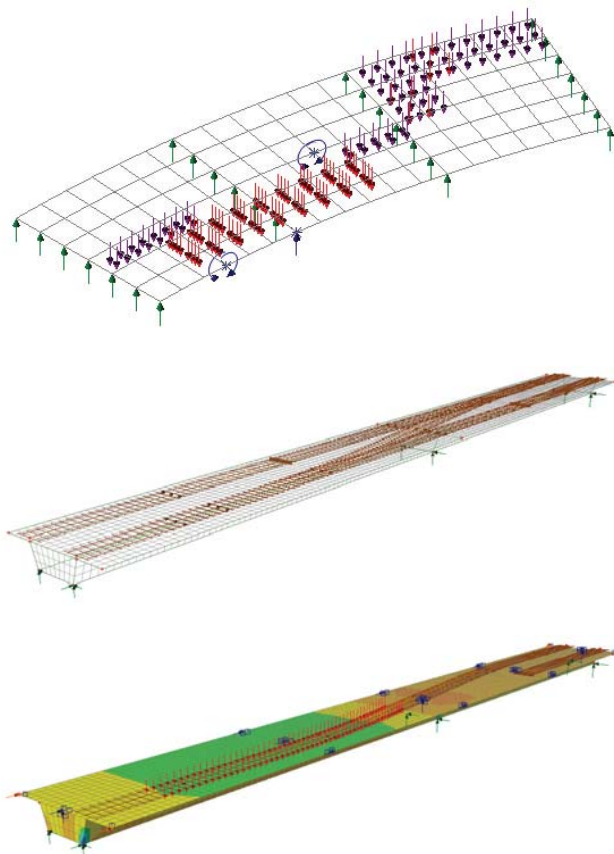
Vehicle loading facilities in LUSAS Bridge software make the generation of live loads very straightforward, speeding up the task of defining the loading imposed on a bridge deck.

- Static vehicle and train loading options for many international bridge design codes including AASHTO and Eurocode are provided. Load trains can be created using a compound load facility. Abnormal load generators are included.
- Vehicle and train loadings can be used either on their own or with a moving load generator to automatically create the required set of loadcases as a loading type makes its way across a bridge.

Vehicle Load Optimisation

Significant amounts of time can be saved with the Vehicle Load Optimisation software option, which automatically generates the most adverse live load patterns for multiple lanes of vehicle (road) traffic, or tracks carrying train (rail) loading, in accordance with a variety of international design codes. The input of a few parameters enables an optimised load pattern to be generated for shell/plate element models and line beam models (vehicle loading only).

- Vehicle load optimisation reduces the amount of time spent generating loadcases to replicate live loading on models, and leads to more efficient and economic design, assessment or load rating of bridge structures.



Envelopes and Combinations

- Basic load combinations allow for manual definition of loadcases to be included and load factors to be used. In situations when superposition may not hold true, the factored loadcases from these combinations can be used to create a single loadcase for a nonlinear solution to be found.
- Envelopes of multiple loadcases provide maximum and minimum results.
- Smart Combinations generate maximum and minimum results, taking account of adverse and relieving effects, substantially reducing the number of combinations and envelopes required.

Design Code Load Combinations

By assigning a loadtype to a loadcase, envelope or basic combination for a supported code, design code load combinations for those load types are automatically generated by LUSAS Modeller. Design codes supported include AASHTO, AS/NZS 1170, Eurocode and others.



Staged construction modelling

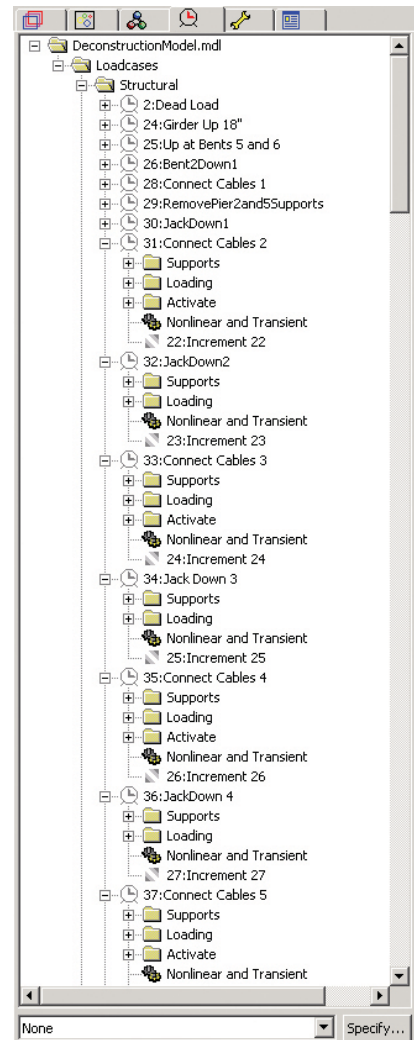
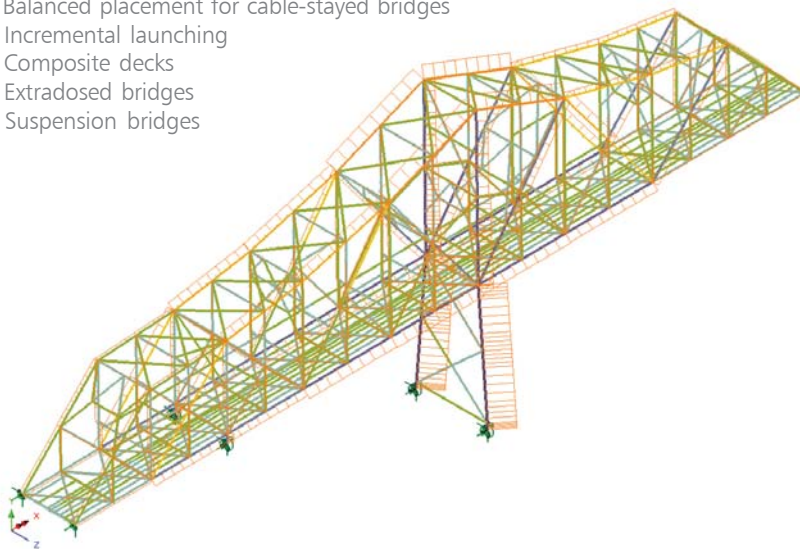
Staged construction modelling is essential for many forms of bridge design and construction. LUSAS provides you with the means to model the construction or dismantling of your structure over time, and evaluate the effects of structural changes, load applications, and any time-dependent material changes.

With LUSAS, unlike some software, only one model file need be created and this can contain all of the information required to carry out an analysis of every stage of bridge construction. The effects of geometric and material nonlinearity, and time-dependent material effects such as creep and shrinkage can all be included.

A complete staged construction modelling process for a model is controlled in the Analyses panel of the LUSAS treeview. When modelling, groups of elements and their associated attributes can be activated and deactivated, with supports being carried forward between loadcases, introduced or removed to accurately represent each stage. Construction history tables containing displacement history and incremental displacement results can be produced.

Use for all types of staged construction methods / bridge types including:

- Staged placement of beams and slab for continuous structures
- Cast insitu span-by-span construction of continuous beams
- Precast segmental span-by-span erection
- Cast insitu balanced cantilever construction
- Precast segmental balanced cantilever construction
- Progressive erection of precast segmental decks
- Balanced placement for cable-stayed bridges
- Incremental launching
- Composite decks
- Extradosed bridges
- Suspension bridges



Dismantling of 1930s steel bridge trusses and cantilever spans involving staged construction modelling of the existing structure incorporating all renovations made during its lifetime, followed by a detailed stage by stage demolition analysis to ensure safe removal of the structure.





Geotechnical / soil-structure modelling

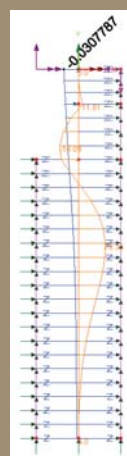
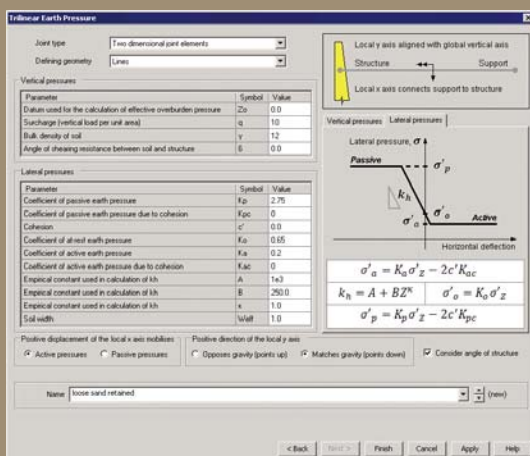
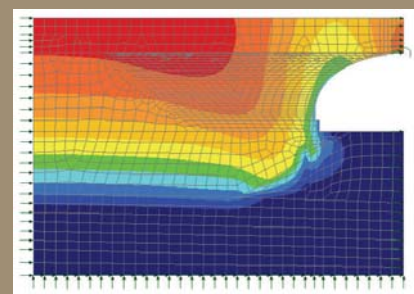
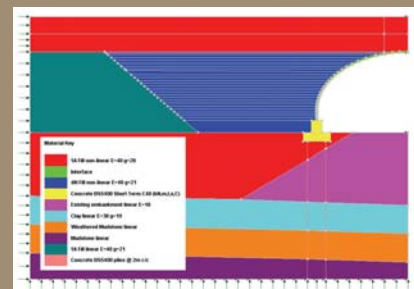
Unlike some structural analysis software, LUSAS Bridge analysis software provides a range of soils-specific and general structural engineering analysis tools to allow finite element modelling of both ground and structure in a single model. State-of-the-art element libraries, advanced material models, and linear and nonlinear joint models, allow a range of soil-structure engineering problems to be solved.

Useful geotechnical capabilities make use of a range of soil models. Residual soil stress varying with depth can be accommodated providing useful facilities for soil-structure interaction for integral bridges and culverts. Rock joints, pore water pressure dissipation, consolidation modelling, geotechnical problems involving long term excavation, construction in clays, and temporary works can all be solved.

Constitutive soils models include Tresca, Von Mises, Drucker Prager, Mohr Coulomb, and Modified Cam Clay. Two-phase material properties can be added to selected materials to permit modelling the deformation of undrained/fully saturated and fully-drained/unsaturated porous media, and slow consolidation process. Draining and filling curves can also be specified for partially drained materials.

Nonlinear springs model active/passive soil joints. Interface meshes permit joining of the soil / structure. Gain / loss of contact, and skin friction can be considered.

A tri-linear active / passive earth pressure joint material wizard simplifies the modelling of a variety of soil-structure interaction problems, creating a piecewise linear joint material attribute with properties that vary with depth. Multiple attributes can be defined to represent layers of soil or changes in properties due to the presence of water.



Use for:

- General soil-structure interaction
- Integral bridges
- Retaining walls
- Pile and pile group analysis
- Tunnelling / cut and cover tunnels
- Excavation and construction
- Embankment / slope stability
- Settlement and consolidation
- Dewatering and seepage analysis
- Modal and time-history dynamics



Detailed linear, nonlinear and pedestrian moving-load and steady-state analysis using LUSAS assisted in the development of the first major highway infrastructure project designed and constructed to Eurocodes in the UK.



Analysis and design

When designing your structure, multiple analyses can be defined and solved independently from within one model. This means that, in most cases, there is no need to create separate models, and maintain clone copies of a model, in order to analyse and view results for different analysis requirements. The main analysis capabilities are summarised here.

Linear static

Stresses, strains, displacements, moments, shears and axial forces that result from static loading are easily calculated, displayed and output from any model.

Cable tuning analysis

The linear cable tuning analysis facility calculates load factors for cables in order to achieve defined target values set for various feature types or results components. An 'exact' method, an optimisation facility and two best-fit solution methods are provided. A nonlinear cable tuning loadcase facility is also available.

Target values analysis

The target values facility is a post-processing tool that provides a general method of varying load factors in a linear analysis to try and achieve target values defined for particular feature types or results components.

Buckling

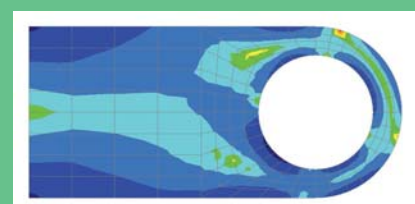
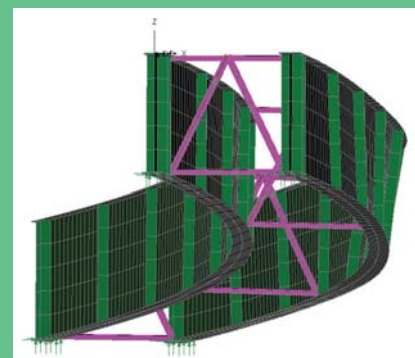
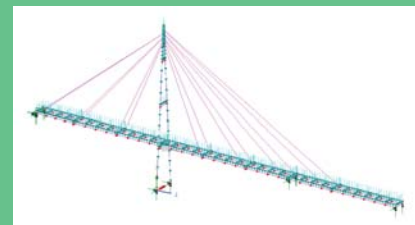
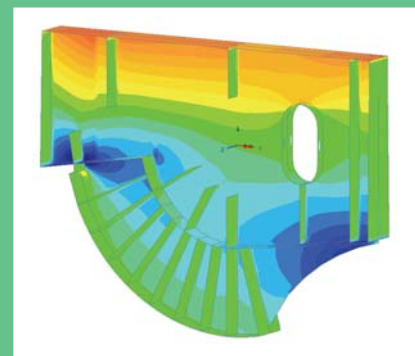
LUSAS carries out elastic critical buckling, which is required for the calculation of member resistances. Often it is also required by some codes to determine if a second-order analysis needs to be carried out. If so, a full nonlinear buckling analysis can be undertaken.

- For existing structures, assessment or load rating to regional design codes can give conservative results showing they 'fail' buckling checks, but detailed buckling analysis with LUSAS can often reveal additional 'hidden' capacity and prove a load capacity.

- For new plate girder, box or tub girder bridge designs, linear and nonlinear buckling analysis using LUSAS can investigate the girder stability during erection, look at the effects of a slab casting sequence, and also help to optimise the size of the web and flange plates, bracing, stiffeners and position of any temporary supports used.

Fatigue

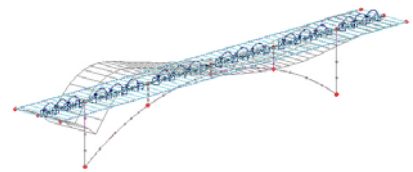
Fatigue calculations can be carried out using the total life approach. Fatigue life may be expressed in terms of the damage that is done to the structure by a prescribed loading sequence or as the number of repeats of a sequence that will cause failure





Influence analysis

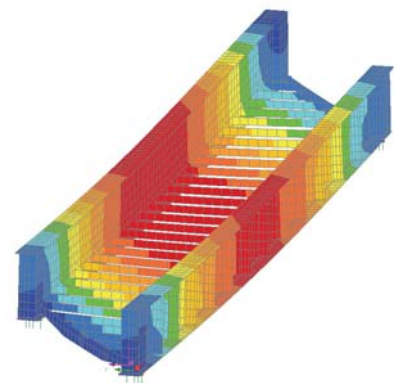
Reciprocal and Direct Method influence analysis are supported. The reciprocal method, also known as the Muller-Breslau Theorem, or Maxwell's Theorem is a means of calculating an influence by the use of an auxiliary structure, to which a deformation corresponding to a load effect of interest is applied. The Direct Method is a general and more powerful way of calculating influences for line beam, frame, grillage, slab and deck models. The effect of a specified point load is assessed at each node or grid location on a loadable area of a structure. The influence can be calculated for any results entity / component according to the elements used, as well as for user-defined results components, and for many locations and quantities within a single analysis.



Dynamics

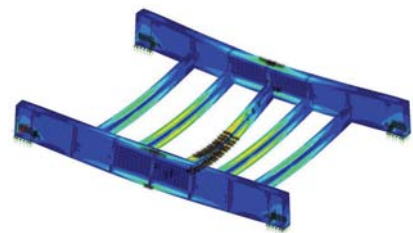
LUSAS Bridge excels in solving seismic and general dynamics problems. The natural frequency of structures; the effect of dynamic loading, such as train loading on through bridges, or pedestrian loading on footbridges; and responses due to earthquake or impact loading can all be readily calculated. Capabilities include:

- Pedestrian excitation
- High speed rail dynamic effects
- Seismicity
- Vehicle and ship impact
- Blast loading



Interactive Modal Dynamics (Modal superposition)

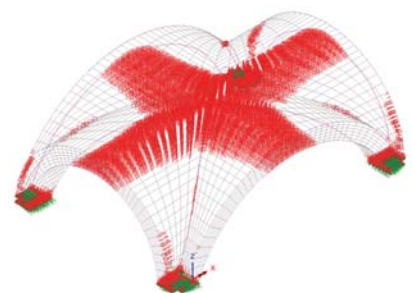
Interactive Modal Dynamics (IMD) allows the natural vibration behaviour of a structure to be combined with a loading regime in order to calculate the dynamic response of a structure to a range of applied excitations. The use of IMD produces results an order of magnitude faster than traditional time-step solutions. Multiple and more advanced loading events including moving loads, moving mass and moving sprung mass, and seismic analysis, can be modelled with IMDPlus and other software options.



Nonlinear analysis

LUSAS Bridge can handle geometric, material and contact nonlinearity to accurately model structural behaviour. Local and global nonlinear analysis with LUSAS helps ensure that bridges and bridge components are designed economically and safely for any imposed loading. Automatic nonlinear solution procedures simplify the analysis process for applications such as:

- Elasto-plastic large deflection plate buckling
- Large deflection cable analysis
- Time-dependent dynamic analysis
- 'Push-over' analysis
- Concrete modelling
- Masonry arch analysis
- Soil-structure interaction
- Integral bridge design
- Bearing analysis, bearing lift-off, and bearing collapse





Design code facilities

Two software options allow for design checking of members in steel and reinforced concrete frames.

Steel frame design

The Steel Frame Design software option provides full details of all calculations made, referencing all relevant clauses and equations from a design code - giving a step-by-step calculation transparency normally only found in simple frame analysis software.

Results are viewed as Utilisation ratios on the model, or as a tabular summary for selected members and loadcases. When added to a model report, results are automatically updated each time to match the current state of the model.

Bridge design codes supported:

- AASHTO LRFD 7th Edition (2014)
 - AS 4100-1998 Steel Structures (Australia)
 - CSA S6-14 Canadian Highway Bridge Design Code
 - EN1993-2: 2006 (Bridges)
- ...with more being added with each release.

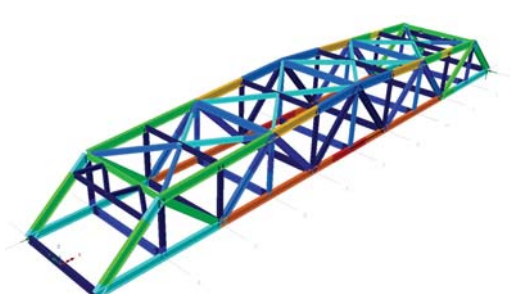
RC frame design

The RC Frame Design software option carries out checking of reinforced concrete members subject to bending and axial force at Ultimate Limit State (ULS) and Serviceability limit states (SLS). Regular, arbitrary shaped, tapering and voided members are supported. Layers of reinforcement are defined for each cross-section along with how individual reinforcement arrangements apply over the lengths of lines representing concrete members.

Results are viewed as Utilisation ratios on the model, or as a tabular summary that allows drilling-down into detailed results and creation of interaction diagrams for selected members and locations. Results can be added to a report.

Bridge design codes supported:

- EN1992-2:2005 - EN1992-2: 2005 Eurocode 2
- ...with more being added with each release.



EN1993-1-1:2005+A1: 1.3 design checks

Design Calculation

Utilisation for combined bending and axial compression buckling **6.3.3(0)**

$$U_{F_x, M_y, M_{z, buck}} = \max(F_x, M_y, M_{z, buck}) = \max(0.71884, (0.718937)) = 0.718937$$

Exp (6.6)

Combined bending and axial compression buckling check 1

$$F_x, M_y, M_{z, buck} = \frac{N_{Ed}}{F_{tEd}} + k_{yy} \frac{M_{y, Ed, max} + \Delta M_{y, Ed}}{E I_{yy}} + k_{zz} \frac{M_{z, Ed, max} + \Delta M_{z, Ed}}{E I_{zz}}$$

$$= \frac{(73.9208)}{(10.3521) \times 10^3} + (1.3750) \frac{(10.0011E-15) + (0.0)}{(1.0) (12.103)} + (0.9450) \frac{(40.7644E-15) + (0.0)}{(1.0) (12.103)}$$

Exp (6.6)

Moment about y-y axis due to shift of centroidal axis according to 6.2.9.3 $\Delta M_{y, Ed} = 0.0$ Table 6.7

Moment about z-z axis due to shift of centroidal axis according to 6.2.9.3 $\Delta M_{z, Ed} = 0.0$ Table 6.7

Combined bending and axial compression buckling check 2

$$F_x, M_y, M_{z, buck} = \frac{N_{Ed}}{F_{tEd}} + k_{yy} \frac{M_{y, Ed, max} + \Delta M_{y, Ed}}{E I_{yy}} + k_{zz} \frac{M_{z, Ed, max} + \Delta M_{z, Ed}}{E I_{zz}}$$

$$= \frac{(73.9208)}{(10.3521) \times 10^3} + (0.9450) \frac{(10.0011E-15) + (0.0)}{(1.0) (12.103)} + (1.3751) \frac{(40.7644E-15) + (0.0)}{(1.0) (12.103)}$$

Exp (6.6)

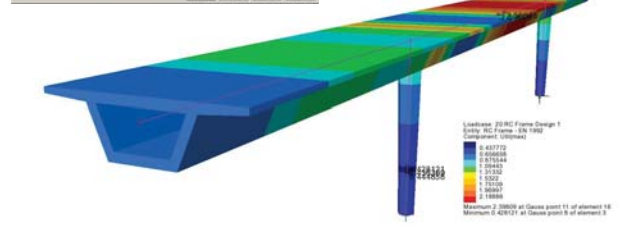
Section Reinforcement

Shape outline from: 3 Check Normal (lock)

Face Data: Layers of rebar | Additional bars

Flow	Face	Layer	No. of Bars	Gap	Bar diameter	Alternate bars	End bars	Start distance	End distance
2	4	1	6	0.0	0.01	Same dia	Some dia	Auto	Auto
2	6	1	6	0.0	0.01	Same dia	Some dia	Auto	Auto
2	4	2	6	0.0	0.01	Same dia	Some dia	Auto	Auto
2	6	2	6	0.0	0.01	Same dia	Some dia	Auto	Auto
2	4	3	6	0.0	0.012	Same dia	Some dia	Auto	Auto
2	6	3	6	0.0	0.012	Same dia	Some dia	Auto	Auto
2	4	4	6	0.0	0.01	Same dia	Some dia	Auto	Auto
2	6	4	6	0.0	0.01	Same dia	Some dia	Auto	Auto

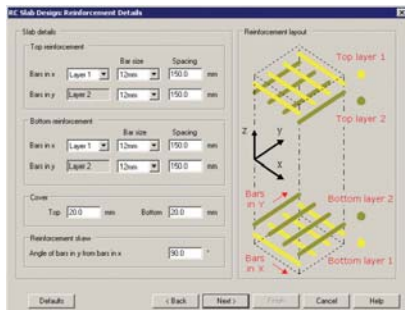
Convert rows to additional bars | Sort | Add | Delete





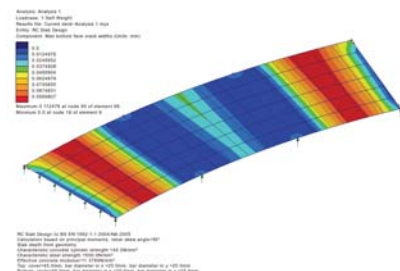
RC slab / wall design

The RC slab / wall design facility is for use with reinforced concrete slabs and walls (without prestressing) that are modelled using plate or shell elements. It enables contours and values that indicate flexural reinforcement requirements at Ultimate Limit State (ULS) to be viewed, as well as calculating design crack widths at Serviceability Limit State (SLS) for those design codes that support this.



Design codes supported include:

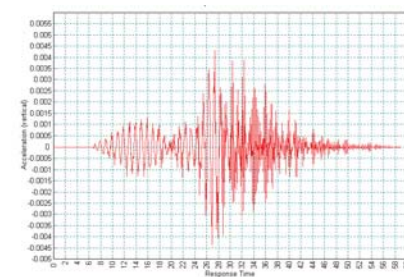
- AASHTO LRFD
 - AS5100-5-2004
 - AS3600-2009
 - BS5400-4, BS8007 and BS8110
 - CAN/CSA S6-06
 - Eurocode EN1992-1-1 and EN1992-2
 - IRC: 112-2011 and CBC-1997
 - SS CP65: Part 1 and 2: 1999
- ...with more added with each release.



Pedestrian dynamics

■ LUSAS models that are used to determine natural frequencies for the simple criterion in EN1990 clause A2.4.3.2(2) can be easily updated to include dynamic actions.

■ The LUSAS pedestrian load wizard creates the necessary moving and varying-magnitude load, based on input such as the recommended Bridge class (NA to EN1991-2, Table NA.7)



Concrete creep and shrinkage

Creep and shrinkage material models may be used in conjunction with certain LUSAS concrete models.

- AASHTO LRFD 7th Edition
- CEB-FIP Model Code 1990
- EN1992-1-1:2004 Eurocode 2
- IRC:112-2011
- User - allows user-defined parameters to be specified.

Tendon properties

Tendon properties for which prestress calculations will include time dependent effects for any stage of construction include:

- AASHTO LRFD 5th to 7th Edition
- EN 1992-1-1:2004 Eurocode
- IRC:112-2011

Steel + Composite Deck Design

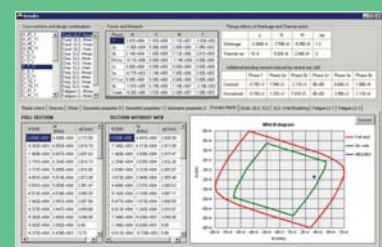
The Steel and Composite Deck Designer software option enables design checking of sections along steel or steel / composite bridge decks to EN1994.

■ Design calculations are carried out covering ULS bending, stress, shear and interaction; SLS stress, web breathing and cracking, and fatigue checks for main members and connectors.

■ Force and moment results for selected bridge elements are exported from LUSAS, and loadcase combinations defined within LUSAS are associated with design limit states and phases defined in the Deck Designer.



■ Section design checks are carried out in the Deck Designer, from which detailed graphs and reports can be also be output.





Viewing results

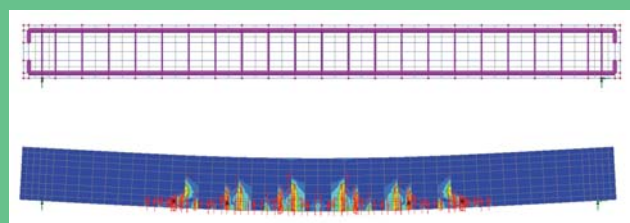
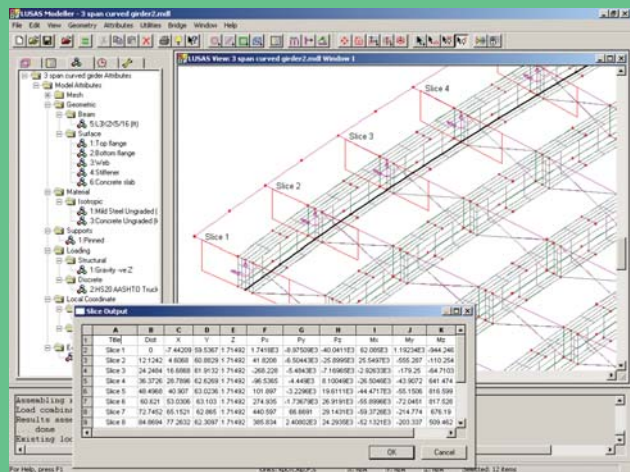
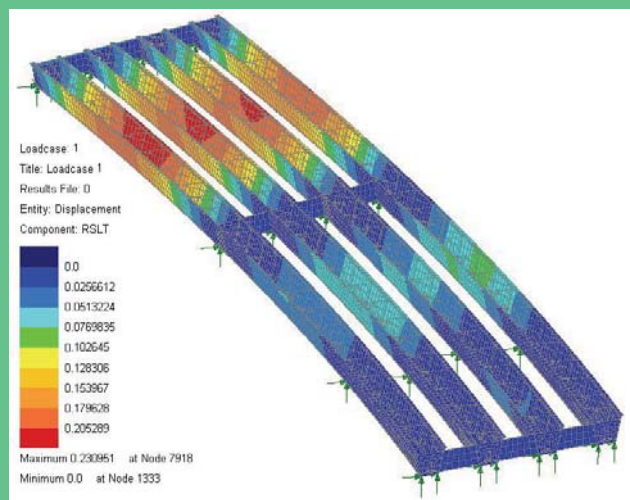
LUSAS Bridge has a host of easy to use results processing and viewing facilities to help you get the most from your analysis.

- Results for all or selected parts of a model can be viewed using separate layers for diagram, contour, vector and discrete value data.
- Loadcases are selected on a window basis, allowing multiple views of the model, with each window displaying results for different loadcases.
- Basic load combinations allow for manual definition of loadcases to be included and load factors to be used.
- Smart Combinations generate maximum and minimum results, taking account of adverse and relieving effects, substantially reducing the number of combinations and envelopes required.

- Envelopes of multiple loadcases provide maximum and minimum results.
- Bending moment and shear force diagrams can be plotted and structural deflections visualised.
- Contour ranges and vector/diagram scales can be controlled locally in each window or set globally to apply to all windows.

- Results can be displayed in global or local directions, in element directions, or at any specified orientation
- Results can be plotted on deformed or undeformed mesh plots and on fleshed or unfleshed beam sections.

- Multiple slices may be cut through 3D solid models on arbitrary planes and made visible or invisible in any window.
- Results can be selectively output to spreadsheet applications for additional calculation and graphing uses
- For concrete modelling, plotting of crack width contours, cracking and values can be carried out for supported design codes by a variety of means.





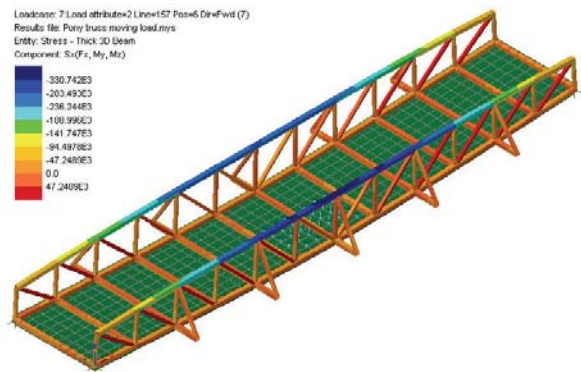
User-defined Results

An in-built user-defined results calculation facility allows LUSAS model and results parameters to be used in arithmetic expressions to give spreadsheet-style capabilities inside all LUSAS software products. Unlike external spreadsheet calculations, because all calculations are done inside LUSAS and based upon current model and results data, the values obtained can be automatically be recalculated at the press of a button if the model data is edited or if results change.

Entry	Expression	Name	Description
1 ForceMoment - Thick Plate	460	fy	yield stress of steel
2 ForceMoment - Thick Plate	420	d	effective depth
3 ForceMoment - Thick Plate	40	tcu	cube strength
4 ForceMoment - Thick Plate	1340	As	area of steel
5 ForceMoment - Thick Plate	1000	b	width
6 ForceMoment - Thick Plate	$(1-1.1*fy*As/(tcu*b*d))*d$	ze	lever arm
7 ForceMoment - Thick Plate	$0.87*fy*As*ze/1e6$	Mu	ULS Moment capacity
8 ForceMoment - Thick Plate	Mx/Mu	Usage	Usage ratio

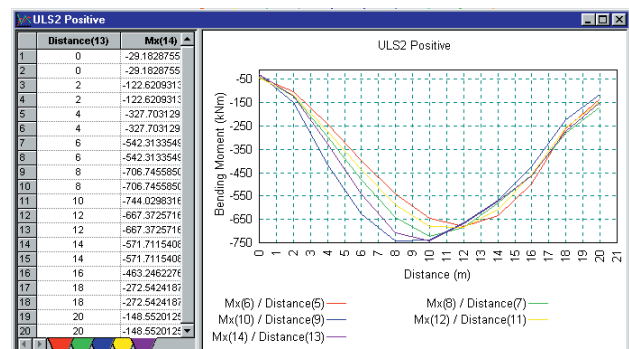
Animations

Animations of results - particularly useful for animating mode shapes, viewing of structural response to moving loads and seismic events, and for investigating the spread of concrete cracking or yielded material - can be created and saved as AVI files for use in other Windows applications.



Graphing

A graph wizard provides a step by step means of selecting results data to be drawn on a graph. Arbitrary line sections may also be taken through any surface model or on a slice cut through a three dimensional solid model.



Construction tables

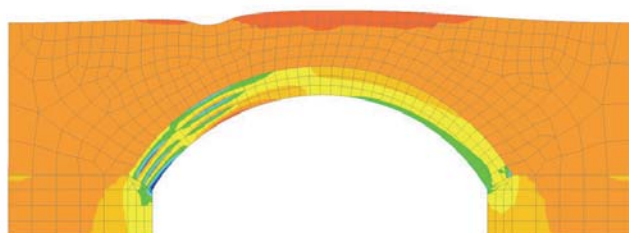
Camber, displacement history, and incremental displacement results tables can be produced for selected model locations to assist staged construction work.

Printed results

Results values for individual results components and entities can be tabulated using the Print Results wizard. These may be transferred to other applications using standard Windows copy and paste operations. Model and results views can be printed directly, saved as high resolution BMP, JPG, or WMF files, or be copied and pasted direct into other applications.

Report generation

One-click reports can be created for selected members, and general modelling, loadcase and results data can be selected on an element, feature type, group, and loadcase basis for inclusion in a main report. Screenshots, saved images, graphs and one-click reports can also be included. Each time a report is created, up-to-date modelling and results data is used to ensure compatibility at all times. Report data may be exported to Excel spreadsheets, Word and other formats.





Software customisation

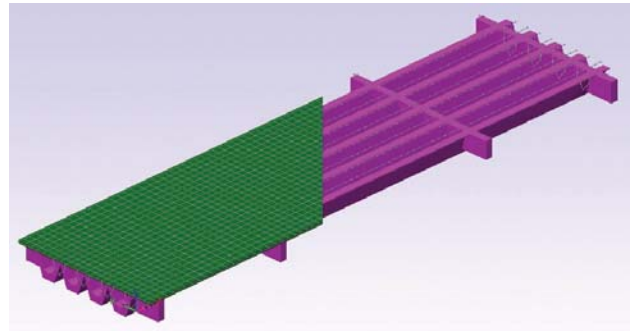
LUSAS software is highly customisable. The LUSAS Programmable Interface (LPI) provides the means to create user-defined menu items, dialogs and toolbars and customise modelling and results processing tasks to your specific requirements.

LUSAS Programmable Interface (LPI)

The LPI is a powerful tool for customising and automating LUSAS operations. By using VBScript (or any ActiveX compliant scripting language, such as Jscript, Perl, Python, C++, C# etc.) to access LUSAS facilities and functionality, you can:

- Create user-defined menu items, dialogs and toolbars
- Interrogate all aspects of a LUSAS model
- Customise modelling operations
- Automate repetitive tasks
- Import CAD geometry and properties
- Create parameterised models
- Make direct links to Word and Excel for import or export of data
- Calculate reinforcement quantities
- Perform simple / codified design checks, and when used with automated iterative analysis structural member sizes and configurations can be optimised

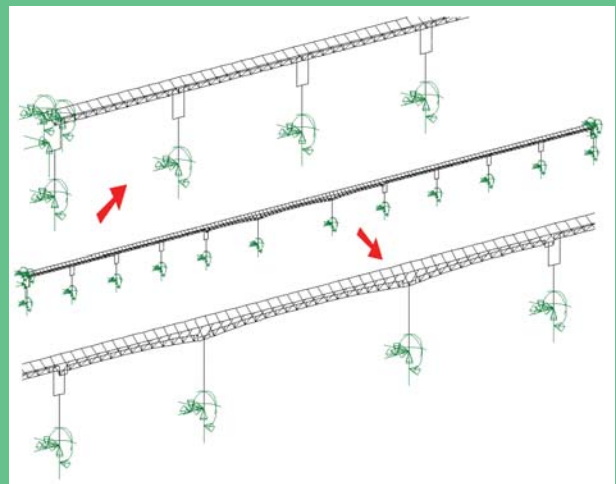
A macro recording facility in LUSAS generates VB scripts for customising. A dialog editor is provided. The use of Visual Basic Runtime means that any VB script can be run in LUSAS.



Advanced scripting users can automate the creation of whole bridge spans for beam and slab decks incorporating prestress, design checks and output reports in MS Word.

Case study

VB scripting assisted in the model building and analysis of seismic resistant viaduct structures and station guideways for Contract C270 on the Taiwan High Speed Rail Project. For this project, a 38km long viaduct required the creation of 70 separate models. A Visual Basic Script read geometric data, such as column dimensions, span lengths etc from an Excel database and built 3D beam models automatically in LUSAS for global seismic analysis and track-structure interaction assessment. Models were created quicker and with more confidence than by manual methods. Subsequent response spectrum analysis with LUSAS determined forces in columns; a track-structure interaction analysis derived relative movements and stresses within the rails under earthquake loading; and a nonlinear soil-structure analysis determined stresses in piles and pilecaps - all resulting in an economical design within a demanding project time-scale.



As used to assist with the design of this landmark asymmetric, cable-stayed, pedestrian swing bridge, that spans the Manchester Ship Canal at the MediaCity UK development.





Software options

The analysis capabilities of particular LUSAS Bridge software products can be extended by purchasing any of the following software options.

Fast Solvers

A range of additional solvers including: a Fast Multifrontal Direct Solver, a Fast Multifrontal Block Lanczos Eigensolver, a complex eigensolver and a Fast Parallel Direct Solver and Fast Parallel Iterative Solver. Provided by default for all new sales.

Vehicle Load Optimisation

Automatically generates the most adverse live load patterns for multiple lanes of vehicle (road) traffic, or tracks carrying train (rail) loading, in accordance with a variety of international design codes. Provided by default for all new sales.

Steel Frame Design

Provides full details of the calculations made, referencing all relevant clauses and equations from a design code. Gives a step-by-step calculation transparency normally only found in simple frame analysis software. View results as Utilisation ratios on the model for a selected design code and loadcase. Full details of the design checks undertaken can be written to a model report.

RC Frame Design

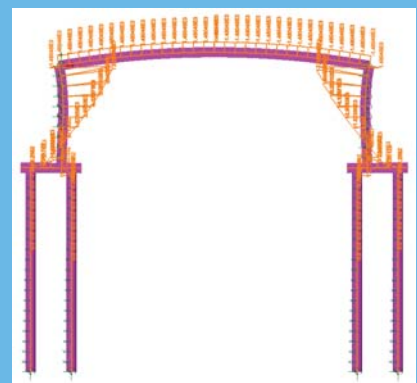
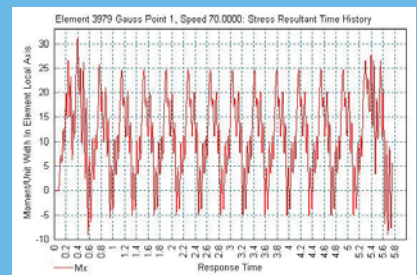
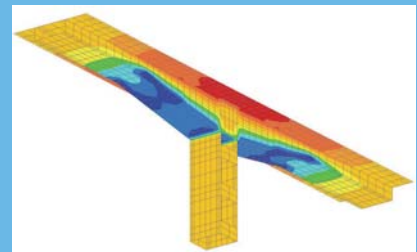
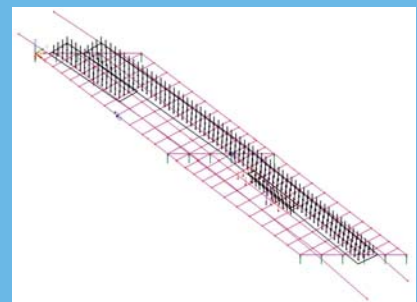
Provides design checking of regular and arbitrary shaped reinforced concrete members subject to bending and axial force. View results as Utilisation ratios on the model for a selected design code and loadcase. Produces a tabular summary of design check results, and allows drilling-down into detailed results and creation of interaction diagrams for selected members and locations.

IMDPlus

Extends the Interactive Modal Dynamics (IMD) techniques available in all LUSAS products, and which model a single loading event in a single direction, to allow multiple loading events with more advanced loading conditions to be solved. IMDPlus is used for two primary uses: seismic response analysis of 2D and 3D structures subjected to acceleration time histories of support motion, and for the analysis of 3D structures, such as bridges, subjected to constant moving vehicle or train loads, or moving mass or moving sprung masses.

Nonlinear Analysis

Provides powerful techniques for solving problems having either: geometric nonlinearity (large deformations, finite rotations and large strains); material nonlinearity (concrete, steel, rubber and geotechnical material models) or contact nonlinearity (point and surface). The nonlinear analysis option can be used to solve a multitude of problems having large deformations, high levels of material nonlinearity and complex boundary conditions. It can also be combined with the LUSAS Dynamic and Thermal / Field software options to solve problems in which the effects of time and temperature are important.





Dynamic Analysis

Straightforward modal dynamics problems can be solved using Interactive Modal Dynamics (IMD) techniques which are provided in selected LUSAS Bridge products. The Dynamics option contains the facilities required to solve a wider range of dynamic problems in the time domain with a step-by-step solution. Additionally, by combining the LUSAS Dynamic and LUSAS Nonlinear options, both high and low velocity nonlinear impact problems can be solved using either implicit or explicit solution techniques.

Thermal / Field Analysis

The Thermal / Field software option contains extensive facilities for both simple and advanced steady state, and transient thermal / field analyses. By combining the LUSAS Thermal / Field option with other appropriate LUSAS options, heat transfer due to conduction, convection and radiation can be analysed. In addition, the effects due to phase change of material may also be included.

Heat of Hydration

Modelling of heat of concrete hydration can be carried out for a variety of cement types using the using the Heat of Hydration option. Effects due to the addition of fly ash and ground granulated blast furnace slag can also be included. When used in conjunction with Nonlinear, Dynamic, and Thermal software options the heat of concrete hydration can be computed during a thermo-mechanical coupled analysis, with the temperatures and degree of hydration used by a structural analysis to determine a range of time and age-dependent effects.

Rail Track Analysis

When used with the Nonlinear software option the LUSAS Rail Track Analysis option automates track/bridge interaction analysis for light and high speed rail projects to the International Union of Railways Code UIC 774-3 and Eurocode EN 1991-2:2003 Eurocode 1: Actions on structures - Part 2: Traffic loads on bridges.

Steel and Composite Deck Designer

The Steel and Composite Deck Designer carries out design calculations to EN1994 covering ULS bending, stress, shear and interaction; SLS stress, web breathing and cracking, and fatigue checks for main members and connectors.

Structural Composites Analysis

The capabilities of LUSAS Bridge plus can also be extended by purchasing the LUSAS Composite software product. This includes advanced shell and solid composite elements, easy definition of composite layups, and the ability to carry out analysis, failure prediction and advanced delamination failure modelling on all types of structural composites engineering problem.

option summary

Fast Solvers

- Multifrontal Direct / Block Lanczos Solvers
- Parallel Direct and Iterative Solvers

Vehicle Load Optimisation

- Live load optimisation to design codes
- Identify most onerous loading patterns

Steel Frame Design

- Design code checking of steel members
- Full details of all calculations made

RC Frame Design

- Design checking of concrete members
- Tabular summaries, detailed results.

IMDplus

- Fast multiple loading event evaluation
- Seismic response analysis
- Moving load, mass, and sprung mass

Nonlinear

- Geometric and material nonlinearity
- Contact nonlinearity
- Automatic solution procedures

Dynamic

- Spectral and forced response
- Transient implicit dynamics
- Nonlinear dynamics
- Modal or Rayleigh damping

Thermal / Field

- Steady state and transient
- Temperature distribution / dissipation
- Coupled thermal-structural

Heat of Hydration

- Model a variety of cement types
- Evaluate time-dependent effects

Rail Track Analysis

- Track / bridge interaction analysis to the International Union of Railways Code UIC 774-3 and Eurocode 1

Steel / Composite Deck Designer

- Design checking for steel/composite bridge decks to Eurocode EN1994

Structural Composites Analysis

- LUSAS Composite software product



Software, support and consultancy services

Software availability

Whether your analysis requirements are simple or advanced, LUSAS Bridge can be configured with various levels and options to meet your needs, all of which are fully integrated and easily upgradeable. The configuration can also provide for extra copies of the Modeller independent of the Solver and can be made available as fixed or network (floating) licences over both LAN and WAN for flexible access.

Training services

Detailed LUSAS application training courses get you up-to-speed and also ensure you have sufficient knowledge of the relevant facilities to tackle the analyses you want to do.

Technical support

Our dedicated hot-line technical support engineers will help you to meet your deadlines and to make the most of your company's investment. They are experts in providing sound modelling and analysis advice to fellow bridge engineers in a friendly and informative manner and are regularly praised by clients for providing good and informative assistance.

Web-based support

The LUSAS web site User Area contains a wealth of technical information. Tips and tricks, frequently asked questions and other useful details are provided to assist you in your modelling and analysis tasks. Software scripts and the latest versions of LUSAS can be downloaded for instant use.

Quality assurance

The accurate and reliable results you get from LUSAS Bridge come not only from our continuous development program but also from our use of an automatic installation and testing system. With our quality control procedures, designed to comply with ISO 9001, you can use each new improved version of LUSAS Bridge with the same confidence as the last.

Consultancy services

If you need more assistance than that available through the hot-line service, then our team of engineering consultants can help. Whether you have a difficult analysis to carry out or need help with a peak workload, our rapid and cost-effective service will ensure you get the best out of your designs.

Find out more

Clients worldwide are benefiting from the commercial advantage that LUSAS Bridge gives them and testimonials on their use of the software speak for themselves. Whilst this brochure provides only a broad overview of the main facilities and benefits of using LUSAS Bridge software, detailed information sheets on key features, analysis capabilities and real-life uses of the software are also available.

For more details, or to arrange a demonstration, please contact LUSAS or your local distributor and find out just what LUSAS Bridge could do for you.



LUSAS