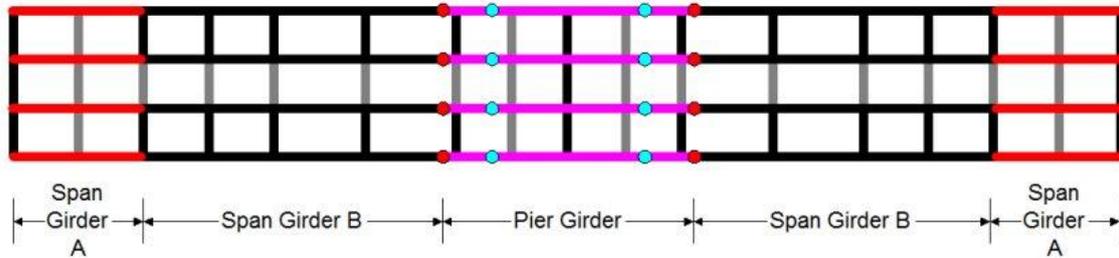
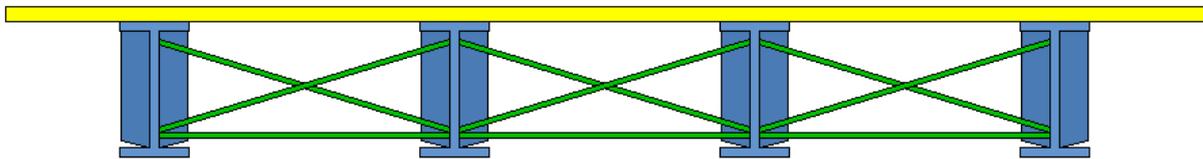


Multi-span composite bridge with bracing

Summary data



Plan on proposed grillage model



Indicative Cross Section

Exercise

1. Build the model using the illustration above and the instructions below.
2. Use the basic checklist on page 6. Do you get the correct reaction and deformation?
3. Display diagrams of moment (M_y) under temperature profile load. Can you match the plot on page 7?
4. Add staged construction following the instructions on pages 7 and 8.

Support

If you have any questions or difficulties while attempting this worked example, please email your trainer: onlinetraining@lusas.com

Building the model

- Units.** Work in kN, m, t, s, C. These are “consistent” units.
- Analysis Category:** 2D Grillage/Plate. This will give you a vertical Z axis.
- Features:** Point and line features generated using **Bridge > Grillage wizard**.
 - Space beam and slab deck, cracked section 15%, Skew angle 0°
 - Evenly spaced longitudinal beams, width = 7.5, 4No longitudinal beams (giving a spacing of 2.5m)
 - Number of spans 2, Length of each span=20.4m, Number of internal transverse beams = 7 (giving a spacing of 2.55m)

The wizard will split the longitudinal beams at the defined cracked point (15% of span, either side of pier). We want to add in additional splits where the I-beam cross-section changes.

- *Right click > Select All*
 - *Geometry > Slice Geometry.* We want to slice in the YZ plane at an offset of 14.4; i.e. slice everything at X=14.4m.
 - Repeat at X=26.4m.
- Mesh attributes:** 2D GRIL elements with 1 division per line (automatically defined and assigned by the wizard).
 - Geometric attributes:**
 - *Attributes > Geometric > Bridge Deck (Grillage) > Girder with Top Slab*
 - In the Girder tab leave it as Constant section. Click Edit to change the girder. In the dropdowns at the top right, Select Parametric Sections, then I Sections then New. Input the following data and then click OK twice to accept:

I Sections ×

Type: I (Unequal Flange) ▼

Dimensional data

D 1.4

d 1.36

Bt 0.65

Bb 0.65

tft 0.02

tfb 0.02

tw 0.012

r 0.0

Calculated properties

A 0.04232

Ixx 0.0148949

Iyy 0.915613E-3

Ixy 0.0

J 4.22137E-6

Asy 0.0160546

Asx 0.021752

Section details...

Name: Girder A (1)

- In the Slab tab enter the following dimensions:

Bridge Deck (Grillage) Geometric Attribute - Girder with Top Slab

Analysis category: 2D Grillage/Plate

Constant dimensions
 Dimensions vary linearly between stated distances
 Specify effective widths

	b	t	ys	bh	th	Effective width	Distance
1	2.5	0.25	0.0	0.0	0.0	2.5	na

Include haunch in section properties

Reinforcement

	Bar size (Ø)	Spacing (s)	Cover (c)
Top	0.0	0.0	0.0
Bottom	0.0	0.0	0.0

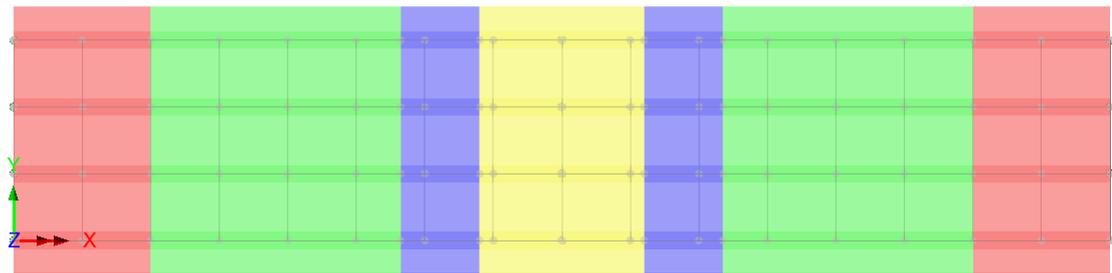
- In the Girder & Slab tab we can keep the default settings for this section. Name it “Span Girder A” and click Apply.
- We then need to create 3 further sections, as follows:

Tab	Girder		Slab	Girder & Slab
Variable	tft	tfb	Reinforcement	Slab
Span Girder A	0.020	0.020	-	Uncracked
Span Girder B	0.020	0.032	-	Uncracked
Pier Girder Uncracked	0.040	0.025	-	Uncracked
Pier Girder Cracked	0.040	0.025	0.012@0.15 0.04 cover	Cracked in tension

- Assign the Span Girder A for the two longitudinal members of each girder adjacent to each abutment
- Assign Span Girder B from there until the additional points we created (at X=14.4 and X=26.4)
- Assign Pier Girder Uncracked until the crack points. And then Pier Girder Cracked for the rest. It should look like this:

Geometric Key
Analysis: Analysis 1

- Span Girder A (Bridge deck - girder with top slab)
- Span Girder B (Bridge deck - girder with top slab)
- Pier Girder Uncracked (Bridge deck - girder with top slab)
- Pier Girder Cracked (Bridge deck - girder with top slab)



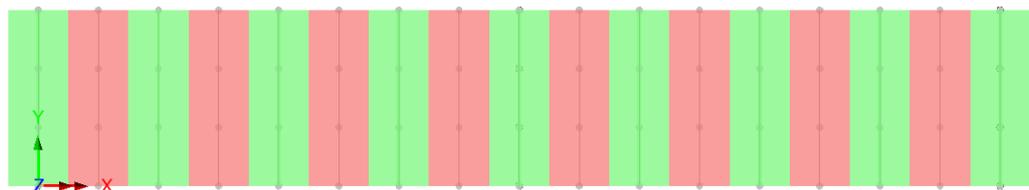
Plan on grillage model showing longitudinal geometric assignments

(Image created by in the Layers tab, double-clicking on Geometry, and changing Colour by=Assignment, clicking Set and choosing Geometric. Also transparency turned on for All)

- We then need to define our transverse sections.
- Transverse Slab: *Attributes > Geometric > Bridge Deck (Grillage) > Slab*
 - $b=2.55$, $t=0.25$. Cracked in Flexure with Approximate cracked properties
 - Name it Transverse Slab and click OK
- Transverse at bracing locations: *Attributes > Geometric > Bridge Deck (Grillage) > Transverse Slab with Bracing*
 - Bracing: Arrangement = Torsional. $h_1=0.2$, $h_2=0.95$. Select both bracing sections as UK Sections, Equal Angles (Advance) and then 150x150x12 UKEA
 - Girder dimensions: Click From Library and then any of our Parametric I sections (they are all the same for the relevant dimensions)
 - Stiffener: $bst=0.3$, $tst=0.03$
 - Slab: $b=2.55$, $t=0.25$. Cracked in Flexure with Approximate cracked properties
 - Name it Transverse Slab with Bracing and click OK
- Assign the transverse attributes by including bracing at the ends, and alternate without/with bracing for the other transverse members. It should look like this:

Geometric Key
Analysis: Analysis 1

- Transverse Slab (Bridge deck - solid slab)
- Transverse Slab with Bracing (Bridge deck - transverse slab with bracing)



Plan on grillage model showing transverse geometric assignments

Material attributes:

Short term Properties

Attributes > Material > Bridge Deck (Grillage) This dialog allows us to define different materials for the various parts of the geometric sections.

The main analysis should always be for short term effects, as its properties are used for VLO. Therefore we want the short term Young's Modulus for concrete. In the Slab box select New and choose Concrete Europe EN1992-2 C40/50, name it Concrete ST.

For the Girder/Bracing select New and choose Steel-Structural, Europe, EN1993-1-1, name it Steel.

For the Rebar select New and choose Steel – Reinforcing Bar, Europe, EN1992-2, grade 500B, name it Rebar.

As this is for short term effects, we are not interested in the mass of the materials, as dead load is a long term effect. Deselect Mass for both the Slab and the Girder/Bracing.

Give the Bridge Deck (Grillage) material the name “Composite ST” and assign to all members.

Long term Properties

Right-click on Concrete ST and Edit attribute. Divide the Young's modulus by 3, to give the effective Long Term concrete stiffness and call it Concrete LT.

Right-click on Composite ST and Edit. Change the Slab material to Concrete LT and name the Bridge Deck (Grillage) material Composite LT.

In the Analysis tab of the treeview, rename Analysis 1 to “Analysis 1 – Short Term”. *Analyses > Structural Analysis*. Name the new Analysis “Analysis 2 – Long Term”. Everything from Analysis 1 will be also used in Analysis 2 unless it is overwritten.

Select all members and assign Composite LT. Make sure it is assigning in Analysis 2 – LT, *not* Analysis 1 – ST.

Support attributes: Fixed in translation Z at the abutments and pier (automatically defined and assigned by the wizard).

Loading attributes and assignments:

Analysis	LCID	Description	Type of loading	Parameters	Assignment:
1 (ST)	1	Differential Temperature: Heating	Bridge > Temperature Profiles > EN 1991-1-5:2003 Approach 2	Annex: Recommended	Longitudinal members only
1 (ST)	3	Differential Temperature: Cooling		Deck type: 2 (normal) Slab depth 0.25 Surfacing 0.125	
2 (LT)	2	Surfacing	Attributes > Loading >	4 node patch	Point at 0,0,0 Search area =

			Discrete Patch	X from 0 to 40.8 Y from -1.25 to 8.75 Load = -23×0.125 = -2.875	whole model Project over area Include Full Load
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NB The patch loading from the surfacing is likely to be on too coarse a grid. In the Attributes tab, under Loading > Discrete is a Patch divisions cog. Double click it, and change to 1 load per search area element.

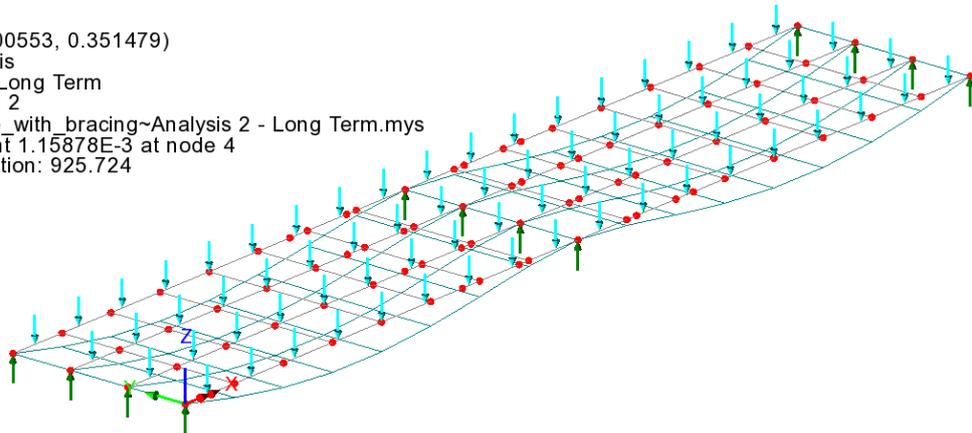
Solve to get results

NB There appears to be a bug in v20, where it will not solve as no geometric attributes are being written. If this happens to you, go to Tools>Mesh>Mesh Reset. This reset seems to kick Modeller into then writing the geometric attributes properly.

Perform a basic checklist on the surfacing loadcase, as it is easiest to verify with a handcalc

1. Total reaction. $23 \times 40.8 \times 10 \times 2.875 = 1173\text{kN}$ Check using *Utilities > Print Results Wizard* [OK]
2. Deformed shape. “If it looks wrong, it probably is wrong”.
3. Magnitude of deformations. Approx 1mm under surfacing – sounds reasonable?
4. Warning messages. Number of warnings = 0.
5. Mesh refinement. Not applicable to grillage analyses

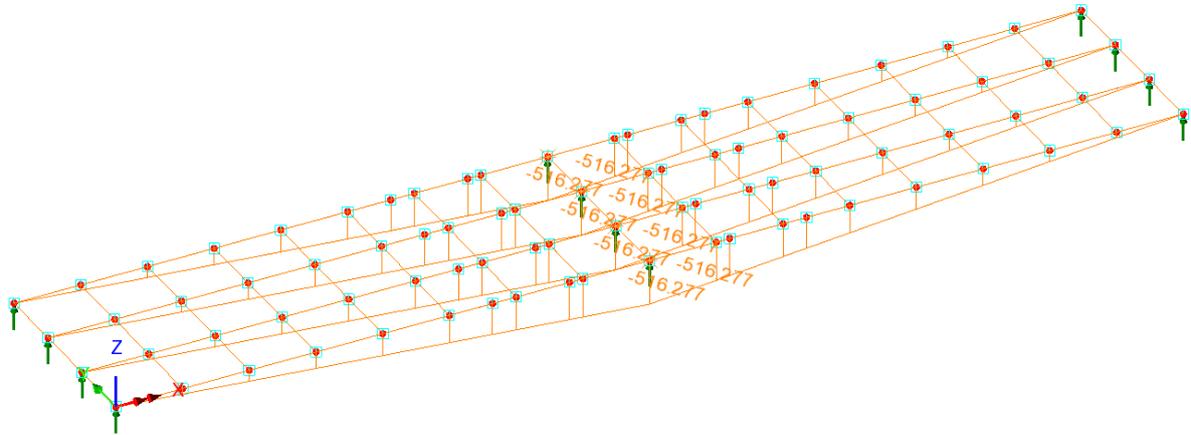
Scale: 1: 178.786
Zoom: 100.0
Eye: (-0.718191, -0.600553, 0.351479)
Linear/dynamic analysis
Analysis: Analysis 2 - Long Term
Loadcase: 4: Surfacing 2
Results file: composite_with_bracing~Analysis 2 - Long Term.mys
Maximum displacement 1.15878E-3 at node 4
Deformation exaggeration: 925.724



3D view on model showing deformed mesh under Surfacing loading

Results

Diagram results



Plan on model showing M_y flexural moments under Differential Temperature: Heating

Staged Construction

Although LUSAS can do full time-dependent staged construction (see https://www.lusas.com/user_area/documentation/V20_0/worked_examples/index.html for worked examples); for the majority of structures analysed as grillages a simpler approach can be taken. As long as you can make the assumption that stresses from earlier stages don't affect the stiffness of the current stage, you can model each stage with its appropriate stiffnesses and loads in a separate analysis, and use the principle of super-position to add all the stresses and deflections together. It is this approach that we will use in this example.

- ❑ **Material attributes:** We need to create two additional material attributes, one for bare steel and one for bare steel with wet concrete
 - Right-click on Composite LT and edit. Give the Slab no stiffness or mass. Give the Steel both stiffness and mass. Name it "Bare Steel" and click Apply
 - Give the Slab mass (but still no stiffness). Remove the mass from the Steel (but keep its stiffness). Name it "Wet Concrete" and click OK.

Analyses > Structural Analysis. Create three new analyses "Analysis 3 – Bare Steel", "Analysis 4 – Deck Pour 1" and "Analysis 5 – Deck Pour 2".

In Analysis 3 – Bare Steel, assign the material Bare Steel to all members. *Bridge > Bridge Loading > Gravity* and assign the created Gravity vertical attribute to all members (to pick up both the girder and bracing weight), to the loadcase in Analysis 3.

In Analysis 4 – Deck Pour 1, assign the material Bare steel to the Pier Girder longitudinal and transverse members. Assign the Wet concrete material to the Span Girder A, Span Girder B, and associated transverse members. Assign the Gravity vertical attribute to the longitudinal Span Girder A and B members (do not assign to the transverse members; we do not want to double count the slab weight), to the loadcase in Analysis 4.

In Analysis 5 – Deck Pour 2, assign the material Wet concrete to the Pier Girder longitudinal and transverse members. Assign the Composite LT material to the Span Girder A, Span Girder B, and

associated transverse members. Assign the Gravity vertical attribute to the longitudinal Pier Girder members (do not assign to the transverse members; we do not want to double count the slab weight), to the loadcase in Analysis 5.

Analyses > Basic combination. Add the loadcases from each of our three staged construction analyses, all with factors of 1. Name this combination “Dead load”.

Discussion

For a full bridge analysis we should also be adding other short term loadcases (temperature range, wind, live load (possibly through VLO), enveloping and then combining them with the dead load; but these are skipped here as they are not unique / specific to grillage analysis.

Quiz

Once you have completed the worked example, please take the Session 1 quiz, accessible from your training index page: https://www.lusas.com/grillage_oct_23/index.html
(https://www.lusas.com/grillage_oct_23/index.html)

Username: **session2**

Password: **IcyDog21##**

Support

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