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Online training course

Session 2 Advanced Grillage Analysis Session will start on the hour



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Session 2

Advanced Grillage Analysis

Presented by: Julian Moses CEng MIStructE

Audio Settings

We are now talking

• If you can't hear us, please click Sound Check, then the Settings cog, then select your speakers



Audio Settings

- If you still can't hear us, please be aware that a recording of this session will be made available afterwards
- But we're now going to move on with the session for the benefit of the majority of trainees who have working audio



Schedule

• 12th October Introduction to Grillage Analysis

• 19th October Advanced Grillage Analysis



Training Format

- 2 hour session
 - Presentation on advanced LUSAS grillage features
 - Demonstration of LUSAS on beam & slab grillage
 - Type questions into the Questions or Chat box
 - Session will be recorded
- Homework
 - Worked Example for you to complete (see handouts)
 - You will need the latest version loaded (20.0)
 - Support available via email (<u>onlinetraining@lusas.com</u>)
 - Quiz to test your understanding



Training Format

- Installation/Licenses
 - You don't need LUSAS installed or a license to watch this session
 - You do need it installed with a license to do the homework!
 - If you don't already have one, please contact your local LUSAS expert and ask them to contact their LUSAS Account Manager



- Can a grillage be used to model complete bridge structure ?
 - Yes the grillage analogy is applicable but more than likely will need to use beam elements rather than grillage elements.

Scale=1:619.953 Zoom: 115.0 Eye: (-0.57735, -0.57735, 0.57735)



• Grillage wizard will only do certain layouts.

More complex layout can be created in modeller or drawn up in CAD





• Use intersection command to create individual grillage lines



• How to use joint elements in a grillage





Grillage modelling

- Overview of last weeks session
- More complex grillage layouts
- Slab and beam section properties
- Stage construction and multiple analysis
- Multi-span composite bridge with bracing example



Structural idealisation

- When analysing a bridge to obtain results of design actions and forces, it is important to realise that what is in fact analysed is not the actual bridge but an idealised mathematical model
 - Stage of design
 - Importance/complexity of the structure
 - What effects are being studied





THE INTERNATIONAL ASSOCIATION FOR THE ENGINEERING ANALYSIS COMMUNITY

"There is a strong tendency for new users of FE to focus on the generation of an accurate geometric model ...

Powerful and alluring graphics ... and facilities to import geometry from 3D CAD packages reinforce this tendency.

The purpose of a finite element analysis is to **model the behaviour of a structure under a system of loads**, not its geometry."

How to model with Finite Elements, Chapter 2



When is a grillage model OK?



Structural idealisation





possible, but not simpler

Creating a grillage model

- Features: a grid of short lines
 - generally along beam centrelines
 - Ideally orthogonal, skews <20° OK
 - Similar spacing longitudinal and transverse
- Grid spacing assumed
 - is equivalent to making an assumption about spreading elastic peaks over a width in an FE model
 - should be determined by rules from Hambly
 - may not improve accuracy if the spacing is reduced



Grillage analogy





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Multi-span composite bridge with bracing demo

• Creating the geometry for the grillage model



Summary data



Indicative Cross Section

Grillage analogy



- They do not carry axial load
- Grillages are for out-of-plane loads only i.e. vertical loads on bridge decks
- Usually 1 element on each side of a grillage bay. But can use more e.g. 2



Flat slab deck types

>60%)



12-36m

- Isotropic slabs
 - Solid
 - Voids <60% depth
- Orthotropic slabs
 - Beam & infill
 - Voids > 60% depth
- Multicellular
 - M-beams
 - Post-tensioned
- Shear key/ box beam

Beam & slab deck options



Beam & slab deck options



- Steel/ plate girder
- Precast
- Rectangular (diaphragm)
- Arbitrary (custom)
- Prismatic or varying

Bridge I	Dec	k (Grillage) Geometric Attr	ribute - Gir	der with Top Slab			— ×
Analy	sis c	ategory 2D Grillage/Plate					
Girde	er s	Slab Girder & Slab					
		Constant section	Varying s	section			
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- Width may vary
- Effective widths
- Include rebar for slabs cracked in tension

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nalysis catego	ry 2D Grillage	/Plate					
Girder Slab	Girder & Slab						
Constant of Constant of Constant of Constant	limensions	Dimensions	vary linearly between	n stated distance	s		
Specify eff	fective widths						
ь	t	ys	bh	th	Effective width	Distance	Insert
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- Treatment of slab
- Torsional constant
- Warping restraint





- Treatment of slab
- Torsional constant
- Warping restraint





Grillage sections – cross-bracing

- Treatment of slab
- Torsional constant
- Warping restraint
- Allows simple inclusion of cross-bracing into section calculation





	Bridge Deck (Grillage) Geome	etric Attribute -	Girder with To	p Slab		×		
• Coming V21	Analysis category 3D	Bridge Deck (G	rillage) Geome	etric Attribute -	Girder with Top Slat	b	×	
0	Girder Slab Girder & Sla	Analysis catego	ary 3D		Bridge Deck (Grilla	age) Geometric Attribute - Girder with	Top Slab	×
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	🗹 Include longitudinal	b 1 2.5	t 0.2	ys 0.0	Slab	Uncracked - concrete only V		100%
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	Name		Name	Tub Girder				
						Name Tub Girder	_	
2								4





Beam & slab grillages

- Torsionless grillages
 - Appropriate for beams of low torsional stiffness e.g. Steel I-girders
 - Simplifies input and output
 - Lower bound theory, so OK
- Downstand grillages
 - Questionable



Downstand grillage



Beam & slab grillages



In-plane distortion of members in upstand grillage model



[where a 3D technique such as downstand grillage modelling is used] "...difficulties arise when in-plane effects are considered... the real problem is the occurrence of localmembers... which are clearly inconsistent with the behaviour of in-plane distortions of the grillage the bridge



Section 7.5

Grillage sections – Multicelular V21

Bridge Deck	k (Grillage) Geom	etric Attribute - Multicellular	×	Bridge Deck	(Grillage)	Geometric Attribute - Multicellular	×
Analysis ca	ategory 3D			Analysis ca	tegory 3D	D	
Slab type	Longitudinal	\checkmark		Slab type	Transverse	• ~	
b	0.0	Average top flange width (wt)	0.0	b	0.0	Average top flange width (wt)	0.0
D	0.0	Average bottom flange width (w	b) 0.0	D	0.0	Average bottom flange width (wb)	0.0
tt	0.0	Flange offsets for visualisation	n	tt	0.0	Flange offsets for visualisation	
tb	0.0	ot 0.0 0	0.0	tb	0.0	ot 0.0 ob	0.0
tw	0.0			tw	0.0		
		Specify torsional constant 🗉	0.0			Specify torsional constant	0.0
	wt		ot -tw D ob	DI		b t t tb	Visualise
И	Name LGeo1			h	lame LGeo1	1] ==



Grillage sections – Multicelular V21

Bridge Deck	k (Grillage) Geometric Attribute - Multicellular X	Bridge Deck (Grillage) Geometric Attribute - Multicellular
Analysis ca	ategory 3D	Analysis category 3D
Slab type	Longitudinal	Slab type Transverse V
b	0.0 Average top flange width (wt) 0.0	b 0.0 Average top flange width (wt) 0.0
D	0.0 Average bottom flange width (wb) 0.0	D 0.0 Average bottom flange width (wb) 0.0
tt	0.0 Flange offsets for visualisation	tt 0.0 Flange offsets for visualisation
tb	0.0 ot 0.0 ob 0.0	tb 0.0 ot 0.0 ob 0.0
tw	0.0	tw 0.0
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	wt tt tt tb tb Visualise	b t t t t v i u v i u v i u v i u v i u v i u v i u v i u v i u v i u v i u v v v v
1	Vame LGeo1	Name LGeo1



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Temperature effects ^{EU}

• Varying temperature profiles (EN1991-1-5):



 $h_{,} = 0.3h$ but ≤0.15m $h_{,} = 0.3h$ but ≥0.10m but ≤0.25m $h_{,} = 0.3h$ but ≤(0.10m + surfacing depth in metres) (for thin slabs, h, is limited by $h - h_{,} - h_{,}$)





Temperature effects ^{EU}

• Varying temperature profiles (EN1991-1-5):





EN 1991-1-5:2003	Approach 2 Tem	perature Profiles		×					
National annex	Recommended	values		~					
Deck type	1a. Steel deck or	n steel girders		~					
Deck thickness	0.25								
Surfacing	Surfaced (enter t	hickness)	 Thickness 	0.04					
Calculated parar	neters								
ΔT1,heat = 24.0°C ΔT1,cool = 6.0°C									
ΔT2,h	ΔT2,heat = 14.0°C								
ΔT3,h	eat = 8.0°C								
∆T4.h	eat = 4.0°C								
Attribute data									
Create temperatur	e attribute for:	Heating							
		Cooling							
Axis of temperatu	re variation								
	🔿 Local y	(Local z						
Consider resulting	g forces								
() A	xial	O Flexural	Bo	oth					
Name TP	rf7			✓ ▲ (new)					
	OK	Cance	l Appl	y Help					

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Multi-span composite bridge with bracing demo

• Creating the base analysis with section properties



Summary data



Grillage – material attributes

Ref	Material	Stiffness	Mass
Slab	1:Concrete (C40/50 Concrete EN1992-2:2005)		1
ander			
inforcem	nt (for cracked sections and design)		
inforcem	nt (for cracked sections and design)		

- Short-term
- Long-term
- Wet concrete...
- Include or exclude stiffness/mass



Multiple analyses

🗗 Layers	💰 Groups	🖧 Attrib	🕒 Ar	nalys 🖌	Utilities	🛄 Rep
⊡. 🔁 Simpl	e grillage v19 ructural analy	0B3.mdl				
	Analysis 1 - Geometr 1:Y7 2:trai 3:Enc	short term ic and slab (Bri nsverse slab I diapragm (E	dge dec (Bridge Iridge d	ck - girder deck - sol leck - gird	with top s lid slab) er with top	slab) p slab)
	2:Sho	ort term prop	erties			
	Carlor Constraints of the second seco	bad upper bad lower m load upper m load lower aper Long term ig term prope ing Dead load t slab t diaphragms	erties			
	Head For the state of the sta	sing 1 traffic 5 traffic n Combinatio n Combinatio	n (M			

- Geometric attributes in Base Analysis
- Short-term material in Base Analysis
- Analysis 2 = long term
 - e.g. concrete slab $E = E_{cm}/3$
- Analysis 3 = wet concrete
 - slab stiffness switched off

Multiple analyses



- Geometric attributes in Base Analysis
- Short-term material in Base Analysis
- It is important to have the base analysis with short-term material properties as this is the analysis that will be used for VLO

Multi-span composite bridge with bracing demo

• Including the stage construction sequence



Summary data





LUSAS Model Attributes





Basic checklist

- Reactions
- Deformed shape
- Magnitude of deformations
- Warning or error messages
- Mesh refinement



Learn more

- LUSAS examples manual
 - <u>https://www.lusas.com/user_area/documentation/V20_0/worked_ex</u> <u>amples/index.html</u>
 - Every step with explanation





Worked Example and Quiz

- Complete Multi-span composite bridge with bracing example
- Session 2 Quiz, on the module and Multi-span composite bridge with bracing example at:
 - <u>https://www.lusas.com/grillage_oct_23/index.html</u>
 (https://www.lusas.com/grillage_oct_23/index.html)
 - Username: session2
 - Password: lcyDog21##
- Questions on the module, example or quiz can be sent to:
 - onlinetraining@lusas.com





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Online training course

Thank you for attending the session

Contact: onlinetraining@lusas.com