Part 24: IPE Beams with a trapezoidal line and surface load

This new part of the handbook of FEM-System MEANS V12 from the website <u>www.fem-infos.com</u> shows how a

beam structure (see Part 06) with a

uniform, triangular and trapezoidal line load

and having a tetrahedral, hexahedral and pentahedral structure with

- uniform, triangular and trapezoidal line load
- uniform, triangular and trapezoidal surface load can calculated.



Exact results according to the beam theory

With the BEAM-Calculator <u>https://calcresource.com/statics-cantilever-beam.html</u> the exact results are calculated according to the beam theory:



Material Datas:









Tetrahedron model with a trapezoidal surface load

A suitable IPE-240 carrier for the FEM calculation can be downloaded in STEP format from the free 3D library <u>www.grabcad.com</u>:



To do this, select "New" and load the "IPE-240.step" STEP file to create a tetrahedral mesh with the GMSH 3D Mesh Generator.

ROJECT	—		×
3D Mesh Generator NETG	EN (STEP,	IGES, ST	°L)
③ 3D Mesh Generator GMSH	I (STEP)		
O 2D/3D Beam Model with L	ine-Modus		
3D Shel Model with a Cont	ainer Mesh	Genenera	tor
O 2D Plane Model with a Bea	aring Mesh (Generator	i.
◯ 2D axialsym. Model with a	Screw Mesh	n Generat	or
NEW PROJ	IECT	1	

In GMSH, select the "3D" menu and the menu 2x "Refine by splitting" to generate a FEM Mesh with 46 272 TET4 elements and 9 975 nodes.



🗏 O X Y Z 🗘 1:1 S 🛙 🖉 🕑 Done refining mesh (Wall 0.078027s, CPU 0.046875s) - 2 Warnings : Click to show messages [... Volume mesh: worst distortion = -3.83695 (avg = 0.655749, 36 elements v

Select the menu "File" and "Export" and export the Mesh in Abaqus INP format back into the same directory of the STEP file so that it can be automatically imported and displayed in MEANS V12.

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Boundary Conditions

The IPE is clamped fixed on the left side. Create it with the "Edit FEM project" tab and "Boundary-Conditions" by selecting the left Surface 6 and confirming with "Create" in the select box.



Create a Range of Nodes for Surface Load

Select the "View" tab and the "Node-Modus" menu as well as the "Surface Nodes" side menu and click on the upper Surface 3 to display all nodes.



Then create with menu "Create a Range of Nodes" with "Coordinates Range" and additional with the option "Create a Range of Range"

	Number of Nodes-	1494	Nou	
		1434	New	
	Create a Range	of a Range	Help	
Selection				
🔘 Drag	igin a model region	O Picking nodes	Coordinate	Range
O Surf.	ace Model			

new range of nodes from Z = 499 mm to Z = 1805 mm inclusive a small tolerance due to the unstructured nodes.

🖳 Create a Coordinate Ra	ange —		×
from X: -57] until X: [64	
from Y: -129.4] until Y: [110.6	
until Z: 499	from Z:	1805	
Create a F	Range of Node	s	

New Range of Nodes for the trapezoidal Surface Load



Now select the "Edit FEM Project" tab and "Surface Load" to create a trapezoidal Surface Load with the following values:

 $W_{1 \text{ Surface Load}} = W_{1 \text{ Line Load}} * b = 30 \text{ N/mm} / 120 \text{ mm} = 0.25 \text{ N/mm}^2$

 $W_{2 \text{ Surface Load}} = W_{2 \text{ Line Load}} * b = 50 \text{ N/mm} / 120 \text{ mm} = 0.42 \text{ N/mm}^2$

with "unequal along Z-axis" and with the selection "all showing nodes"

	Files	View Mesh	Generation	Edit FEM-Pro	oject FE	M-Analysis	Postprocessing
	3.	Surface Load		⊢ •	1. Bounda	y-Condition: *	
ads	1.	Point Load	Boundary	-Conditions	Show Bor	undary-Conditi	ons Element-G
	2.	Line Load		current	Node 11861	- X-Coord.= (53.15; Y-Coord.= 1
	3.	Surface Load					
	5.	Gravitation Load					
	4.	Centrifugal Load	🖳 Loads				\Box \times
	б.	Temperature Load	NAME 1	_			
	7,	Nonuniform Loads	Current L	oadcase:	1	- +	
	8.	Edit Load Case	Number	of Values:		New	
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				() in	Y Direction	vertical to	o Surface
			Selection				
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	a series a s		_ O Sele	ct Nodes	(Select all sho	wing nodes
_	<u>.</u> 3		O Defir	ne a coordinate r	ange () Select all sho	wing surfaces
	$\sum_{i=1}^{n}$						
	1						
	1		С	alculate Value of	f Surface Load	SL-	Color:
			Cancel	Ed	litor	Create a S	urface Load
	0				Γ	Delete	loads
					L	Delete	- Loudo

The result is the following trapezoidal surface loading



With "Show load values" in the Node Modus, the load values can be displayed and checked:



Material Datas

Since the material steel is always preset with a modulus of elasticity of 210,000 N/mm², no material data is required.

FEM Analysis

First save the FEM model under any name on the hard disk, select the "FEM Analysis" tab and calculate a static analysis with the Quick Solver.

🖳 Quick-Solver		-		×
Normal Precision	 show and solve with C3D4 (4-node linear tetrahedral elements) show C3D4 and solve intern with a refining mesh of 8 x C3D4 convert C3D4 -> C3D10 and show and solve with C3D10 	,	\bigwedge	7
Path for INP-Solver:	$\fbox{C:\Program Files\FEM-System_MEANS_V12\Debug\inpsolver\inpsolver\64bit.e}$	B	rowser	
Path for INP Files:	C:\projekte\Line Load\ipe240\tet4_flaechenlast.INP			
	Select Solver In-Core-Solver Out-of-Core-Solver			
	Start FEM-Solver with INP-Interface			
	Setting Help + Infos Cancel			

Postprocessing



After the FEM Analysis, the results can be evaluated using the icon with register "Postprocessing".

Results:			load Care: 1
Con	tour of Displ	acement	
O Noc	dal Stress Co	ntour	O Reaction Forces
() Eler	ment Stress (Contour	O Contour of Forces
Accurac	y:		
Edit	Accuracy:		Displacement Factor
			Edit Colours for Legend
1	3	4	Pick, Search, Save Values
Select R	esult Compo	nent:	
	Displacem	ent in y directior	1. v

Max. Displacement in y direction = -7.88 mm (exactly = -8.19 mm)







Pentahedral model with a trapezoidal line load

To get a pentahedron model, simply extruded the tetrahedron front surface in Z-direction.

Create a 2D Mesh from the front surface

In Surface Modus, select menu "Mesh from Surface Model". In the first step, select the profile surface 9. In the second step you create the triangular mesh with 96 nodes and 100 TRI3S elements with a node check and the option "Delete nodes which are not connected to an element". With the third step the z-axis can be set from 2000 to zero and the x-axis can be swapped with the y-axis



Extrusion

Select register "Mesh Generation" and menu "QUAD-Meshes, Refine, Delete..." as well as in the next dialog box the register "Extrusion" and create the pentahedron mesh with a number of nodes in the Z direction = 81 and a Z object height = 2000 mm.



Select the menu "Create 3D Mesh" to create the pentahedron model with 8240 PEN6 elements and 8019 nodes..



Boundary Conditions

The IPE is clamped fixed on the left side, the BCs are created with register "Edit FEM-Projects" and menu Boundary Conditions" by clicking on to Surface 6.



Create a Range of Nodes for Line Load

In order to generate a trapezoidal line load, a range of nodes must first be defined in the Node-Modus with "Create a Node of Range" "and "Coordinate Range":

归 Create a Range of Nodes	- 🗆 X
Please dragging a model region or picking nodes!	
Number of Nodes= 0	New Help
Selection	
Draggin a model region Picking nodes Surface Model	Coordinate Range
Cancel Create a	a Range of Nodes
🖳 Create a Coordinate Range 🛛 —	D X
from X: 3.1 until X:	3.2
from Y: 110 until Y:	110.6
until Z: 500 from Z:	1800
Create a Range of Nod	es

You should see the following node range with 53 nodes from 500 mm to 1800 mm:



Create a trapezoidal line load

Select the "Edit FEM Project" tab and the "Line load" menu and select the dropdown menu "Trapezoidal load positive" in the dialog box to generate a line load with L1 = -30 N/mm and L2 = -50 N/mm at the node range.

	w Mesh Generation Edit FEM-Project FEM-Analysis Postprocessing	Training	
2. Line Loz bads 🗹 Show Log	ds Boundary-Conditions Show Boundary-Conditions Current Node 34 - X-Coord.= -56.85; Y-Coord.= 1	ups Material-Data 10.6; Z-Coord.= 0	s Editor
	🖳 Create a Line Load	3 <u>115</u>	
	Line Load with a Range of Nodes Point Load -> Line Load Hilfe		
	Loadcases: 0		
	New Loadcase 1		
	trezzoidal Load positive	Help	
	Number of Nodes from a Range of Nodes with Node-Modus: 53		
	X-Length		
	Y-Length		
	Z-Length		
	Create a Line Load		

Then you should see the following node load with 53 load nodes:



With "Show load values" in the Node Modus, the load values can be displayed and checked:



Material Datas

Select register "Edit FEM-Project" and "Material Datas" to enter the material datas for Steel with an E-Modulus of 210 000 N/mm² and a Poisson-Value = 0.3.

	Manua	Material Datas			
2	Name	Material Datas			
	Toungs modulus	210000			
	Poisson Ratio	.3			
	Density	7.600007E-06			
	Heat Coefficient	1E-05			
				l	
Ð	ement Group: 1	Element PEN6	_	<	>
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FEM Analysis

First save the FEM model under any name on the hard disk, select the "FEM Analysis" tab and carry out a static analysis with the Quick-Solver.

💀 Quick-Solver		-		×
Normal Precision	 C3D8 (8-node linear isoparametric element) show C3D4 and solve intern with a refining mesh of 8 x C3D4 C3D20 (20-node quadric isoparametric element) 	*	\bigwedge	>.
Path for INP-Solver:	C:\Program Files\FEM-System_MEANS_V12\Debug\inpsolver\inpsolver64bit.	e 📃	Browser	
Path for INP Files:	C:\projekte\Line Load\ipe240\extrude.INP]		
	Select Solver In-Core-Solver Out-of-Core-Solver			
	Start FEM-Solver with INP-Interface]		
	Setting Help + Infos Cancel			

Postprocessing

After the FEM Analysis, the results can be evaluated using the icon with register "Postprocessing".



Max. Displacements in Y Direction = -8.14 mm (exactly = -8.19 mm)

Max. v.Mises-Stresses = 200.4 N/mm² (exactly = 204 N/mm²)



Sum of Reaction Forces = 52000.05 N (exactly = 52 kN)

