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Scia Engineer Optimizer



Tutorial

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Scia Engineer Optimizer

Scia Engineer 2011

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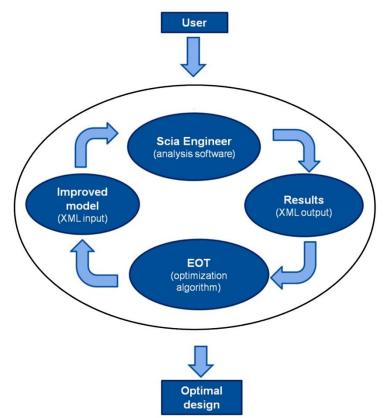
1. Introduction

The aim of this document is to introduce a brand new tool for optimization of civil engineering structures developed by Nemetschek Scia and to demonstrate how it can be helpful and effective to everybody who deals with structural design.

1.1 About Scia Engineer Optimizer

Scia Engineer Optimizer is an example of a new generation of software for the design of structures. It is software which calculates internal forces, checks the compliance to the code, and on top of that, this software is able to "find" the final optimal structural design.

It represents a combination of the widespread structural analysis software - Scia Engineer - and a separate optimization engine (EOT – Engineering Optimization Tool). The two programs have been integrated together and offer a versatile and complete optimization solution for all types of civil engineering structures.



1.2 Motivation

Scia Engineer Optimizer is very general and flexible because the demands which need to be considered during a really optimal structural design are also rather complex and general. However, thanks to the power of the current computational technologies, all requirements for cost reduction, material savings and environmental protection can be now easily met. Despite the complexity of the general optimization, the optimization process itself is not complicated and this manual will lead you how to proceed. Once all the required input data are entered, i.e. the model of the analysed structure is defined, the search for the optimal solution runs fully automatically and no interaction from the user is required. For real-life problems several optimal solutions can be found. In such situations, it is up to the user to make the final decision.

Depending on our requirements we may seek different targets. The goal of the optimization depends on us: is it the total weight, costs, eigen frequency or something else. And with respect to the goal, there are many possibilities of what can be optimized, what means, which properties or parameters of the structure are to be changed to reach the optimum: geometry, cross-sections, reinforcement, prestressing, structural arrangement and others.

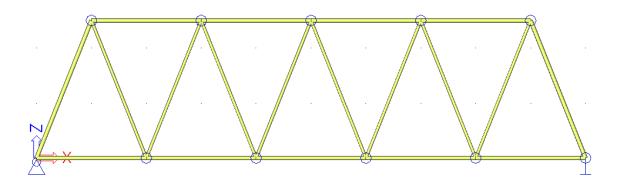
As the constraints we use various values obtained from Scia Engineer analysis: unity check, capacity, eigen frequency, deflection etc.

1.3 Worked example

This example shows the **optimization of the geometrical shape with the aim to reach the minimum mass** of a steel truss girder with respect to fulfilling the capacity according to for 1st limit state code check implemented in SCIA Engineer (EC3 in this case).

The structure is a simply supported truss girder with the span of 10 metres, see the next picture. The goal of optimization is find optimal height of the truss (which will most probably vary along the girder length, see results at the end of this tutorial).

All members have tubular cross-sections but the thickness and diameter are variable. However both values have to be within certain limitations.



2. Structure modelling

2.1 Starting the project in Scia Engineer

First of all the standard Scia Engineer project must be prepared. Therefore, create a model of a structure with all the necessary aspects of the future optimization taken into account.

Run Scia Engineer and create a new project of the Analysis type.

Choose type of new project	×
Analysis Structural Edition	
Empty Scia Engineer project.	OK Cancel

The basic Project data can be filled in according to the picture below:

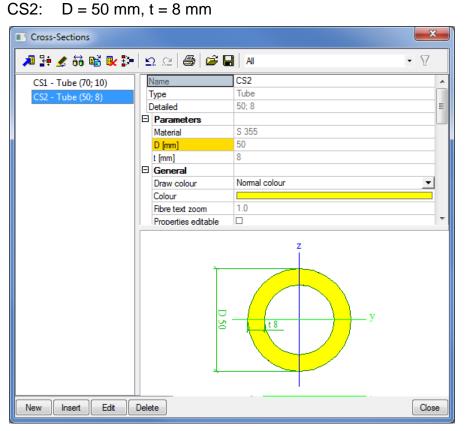
Project data				×
Basic data	Functionality Loads	Protection		
- Real	Data		Material	
A CON	Name:	Steel truss girder	Concrete Steel	
	Part:	Optimization	Material Timber	S 355 <u>▼</u>
	Description:	-	Other Aluminium	
	Author:			
S.	Date:	13. 12. 2011		
A CO	Structure:		Code National Code:	
	General XYZ	•	EC - EN	▼
	Project Level:	Model:	National annex:	
	Advanced	▼ One ▼	Standard I	EN 🔻
				DK Stomo

Although the structure is planar, the structure type is set to **General XYZ** to keep it more general. The project level is set to **Advanced**, which is a generally recommended setting. The code of this particular project is set to EC-EN with the standard EN annex.

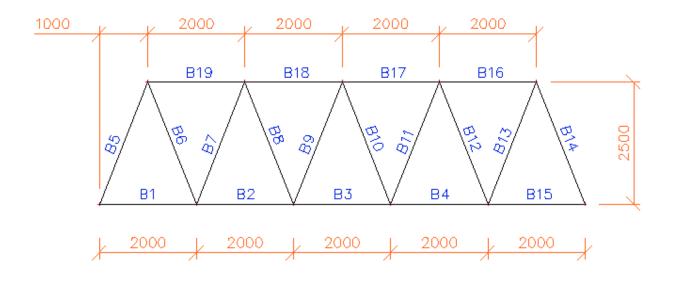
Press OK to confirm the settings and to open a blank project.

Model the truss girder with 1D members. First, you will be asked to select crosssections for the current project. Add two tubular cross-sections with the dimensions:

CS1: D = 70 mm; t = 10 mm

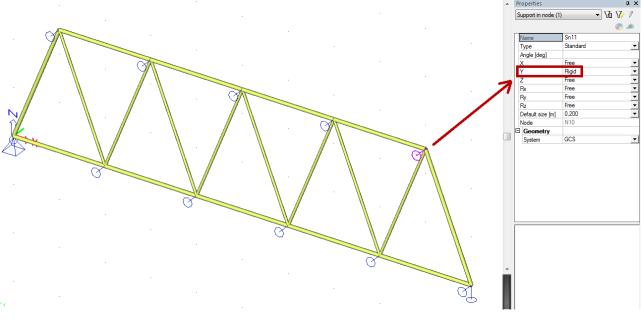


Create the structure according to the following scheme and table:



Name	CrossSection	Material	Length	Shape	Beg. node	End node	Туре	FEM type
			[m]		Ũ			
B1	CS1 - Tube (70; 10)	S 355	2,000	Line	N1	N2	general (0)	standard
B2	CS1 - Tube (70; 10)	S 355	2,000	Line	N2	N3	general (0)	standard
B3	CS1 - Tube (70; 10)	S 355	2,000	Line	N3	N4	general (0)	standard
B4	CS1 - Tube (70; 10)	S 355	2,000	Line	N4	N5	general (0)	standard
B5	CS1 - Tube (70; 10)	S 355	2,693	Line	N1	N6	general (0)	standard
B6	CS2 - Tube (50; 8)	S 355	2,693	Line	N6	N2	general (0)	standard
B7	CS2 - Tube (50; 8)	S 355	2,693	Line	N2	N7	general (0)	standard
B8	CS2 - Tube (50; 8)	S 355	2,693	Line	N7	N3	general (0)	standard
B9	CS2 - Tube (50; 8)	S 355	2,693	Line	N3	N8	general (0)	standard
B10	CS2 - Tube (50; 8)	S 355	2,693	Line	N8	N4	general (0)	standard
B11	CS2 - Tube (50; 8)	S 355	2,693	Line	N4	N9	general (0)	standard
B12	CS2 - Tube (50; 8)	S 355	2,693	Line	N9	N5	general (0)	standard
B13	CS2 - Tube (50; 8)	S 355	2,693	Line	N5	N10	general (0)	standard
B14	CS1 - Tube (70; 10)	S 355	2,693	Line	N10	N11	general (0)	standard
B15	CS1 - Tube (70; 10)	S 355	2,000	Line	N11	N5	general (0)	standard
B16	CS1 - Tube (70; 10)	S 355	2,000	Line	N10	N9	general (0)	standard
B17	CS1 - Tube (70; 10)	S 355	2,000	Line	N9	N8	general (0)	standard
B18	CS1 - Tube (70; 10)	S 355	2,000	Line	N8	N7	general (0)	standard
B19	CS1 - Tube (70; 10)	S 355	2,000	Line	N7	N6	general (0)	standard

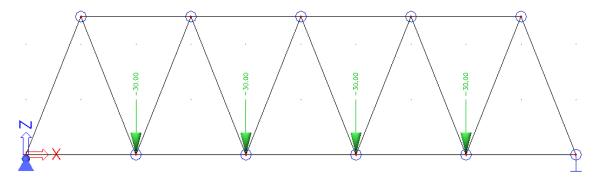
The truss as a whole structure is simply supported. To restrain the lateral displacements, supports in all nodes must be defined to prevent from the deformation in the Y direction.



When the structure is modelled, loads have to be specified as well. The truss girder is subjected to a simple load case with vertical point forces in the bottom nodes. Create a new load case with the action type **Permanent** and load type **Standard**.

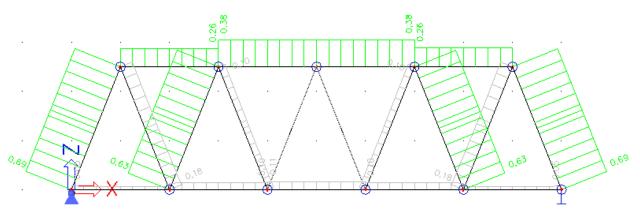
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	Actions		
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	Copy all loads to anothe	rloadcase	>>>
New Insert Edit Delete			Close

This load case is represented by 4 point forces with the magnitude of -30 kN in the Z axis direction (the load is going downwards).



2.2 Calculation and Autodesign

The structure is calculated using standard functions of Scia Engineer first. To see utilization of profiles, a unity check can be performed in **Steel** service, see next picture.

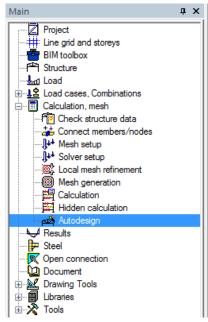


Maximal unity check value 0,69 shows, profiles are too thick. In Scia Engineer we can use very efficient tool to design cross-sections, resulting in a good utilization of individual members under a certain load. The function is called **Autodesign** and it can be found under Calculation, **mesh** group in the Main tree.

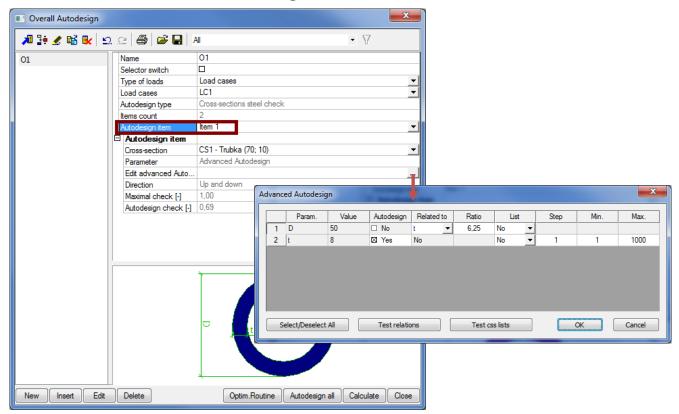
Autodesign can be used for various purposes. The **Cross-section steel check** will be used in this case. This Autodesign function finds an optimal cross-section with respect to the unity check for all members with this cross-section. However, as the change of a profile in a statically indeterminate structure affects the internal forces, the project has to be recalculated. For new internal foces, after recalculation, we can run Autodesign again. The user can do those two steps several times to reach proper cross-section design.

Autodesign is also integrated in optimization loop s of EOT. It means, during iterative search of optimal structure geometry, the program will make design of proper cross-sections. It means, in each iterative step, both geometry and cross-sections will be improved at the same time.

Prepare a new entry (called O1) in the **Overall Autodesign** library. Select both cross-sections (CS1 and CS2) in the selection dialogue. It means that the items count will be 2.



Each cross-section has got two dimensions in their properties – thickness t and diameter D. Both dimensions can be changed upwards and downwards in order to search for the optimum. To optimise both variables in one run, we will keep a fixed ratio between D and t. Advanced Autodesign is used for this.



Overall Autodesign							— X								
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	Autodesign type	Cross-sections st	eel o	check											
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	Autodesign item	Item 2						-							
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It is not needed to do the Autodesign at this moment. EOT application will use this stored setting afterwards.

2.3 Parameters

The optimization is based on parameters. Scia Engineer allows the user to prepare lot of different kinds of parameters, which can be assigned to various entities and/or properties.

In this particular example we want to adapt the shape of the upper chord to get the minimum mass of the structure. This means that some nodes will change their positions (z-coordinates). Therefore, we will to make a set of parameters and we will assign them to properties of nodes.

To make parameters available, we have to switch them on in functionality setting:

Dynamics Dynamics Initial stress Subsoil Nonlinearity Stability Climatic loads Prestressing Pipelines Structural model Parameters Mobile loads Automated GA drawings LTA - load cases External application checks KP1 application Property modifiers		Steel Fire resistance Connection modeller Frame rigid connections Frame pinned connections Grid pinned connections Bolted diagonal connections Expert system Connection monodrawings Scaffolding LTB 2nd Order ArcelorMittal	
		OK	Stomo

Then, let us open parameters library under **Tools > Parameters**. New items can be added with the button **New** in the top left or the bottom left corner (both these buttons do the same).

Tools Modify Tree Plugins Setup	Parameters		
Activity Selections	🗾 🗶 📸 🗽 AI		• 7
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💘 Cursor snap setting	z2	Туре	Length 🗨
Dot grid and tracking setting	z3	Description	
🖨 Layers		Evaluation	Value 🗨
User defined selections		Value [m]	2,50
sta		Use range	
Parameters			
Parameters template settings			
📕 Cleaner			
Coordinates info		Actions	
XML IO Document		Validate	>>>
Convert Steel Profile Db	New Edit Delete		Close

Prepare three parameters which will specify the Z coordinate of nodes of the upper chord. As we need a symmetric structure three parameters will be sufficient. The type of parameters is set to **Length**, Evaluation to **Value** and the default value is **2.5** m at the moment.

Assigning parameter to a node is simple. Just select a node and then, assign the parameter to the value of this property of selected node.

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		🌮 🧆
GCS coordi		
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Coord Y [m]	0,000	-
Coord Z [m]	2.5	-
UCS coordi	Insert value	
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Coord uy [m]		
Coord uz [m]	2,000	
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Select the outside nodes *N6* and *N10* and change their Coord Z to **z1**.

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	Coord X [m]	-
	Coord Y [m]	0,000 💌
	Coord Z [m]	z2 💌
Ξ	UCS coordi	
	Coord ux [m]	
	Coord uy [m]	0.000
	coord dy [m]	

Select the inner nodes *N7* and *N9* and change their Coord Z to **z2**.

GCS coordi	
Coord X [m]	5,000 💌
Coord Y [m]	0,000 💌
Coord Z [m]	z3 💌
UCS coordi	
Coord ux [m]	5.000
Coord ux [m]	0,000
Coord ux [m] Coord uy [m]	0,000

Select the the middle node *N8* and change its Coord Z to **z3**.

When the value of particular parameter is changed, the structure reacts immediately. However, let us assign this job to EOT. It shall calculate the correct value for each of the parameters.

3. XML documents

Scia Engineer Optimizer is an external application and the optimization process is running "outside" Scia Engineer. We need to transfer the necessary information between these two applications. Format XML (Extensible Markup Language) is used for this task.

Scia Engineer has a tool for creating XML documents in a similar way as the basic Scia Engineer output document. Go to **Tools > XML IO Document** and a new window appears.

Tools Modify Tree Plugins Setup	XML Input / Output Document
Activity Selections	DOC-Default
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Layers User defined selections	Description Orfault Entributed document - □ Language Anglithma (Dep v) Pictures alignment Lift v
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📕 Cleaner	First chapter number 1 Orbagter number /Al → Orbagters captors /Al →
Image: Coordinates info Image: The second	Actions Full regeneration of docum
Convert Steel Profile Db	Lad derlings >>> Save sating >>> Lad template _>>>

If you open the XML document for the first time, an option to open the Document template in *.TDX format appears. You can skip this if you don't have any XML template. Hit Cancel button.

Two documents have to be created for each project - one with input parameters and second one with output parameters. These two documents differ in their content which is described below.

3.1 Input XML

The input document has to include the table of parameters only. Click on the **New** button on the top left corner and select **Parameters** table from the Libraries group.

II XML Input / Output Document		X
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	22 (45/8)2EF5-46/E-4/02E-A/36/1-8A6/79/13FFD33 Length Value false Real	
	23 (942AC100-3F FB-4D2F-94A/9-B3/CA076331) Length Value false Real Layers	
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3.2 Output XML

The output document consists of more tables, namely the Bill of material (because mass optimization is the basic task) and Checks of steel (because we want to design the structure as well).

Click the button with three dots at the top and insert a new document.

XML Input / Output Document		
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Click on the **New** button in the top left corner and add the desired tables:



Bill of material from the Results group

Check of steel from the Steel group (this has to be input twice – for each cross-section)

Below you can see the settings for each table included in the document. Note that the check of steel is filtered by cross-section and the first and the second item differ in this setting only.

🔳 XML Input / Ou	tput Document	🔳 XML Input / Ou	tput Document		XML Input / Output	out Document	
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Values	Mass	Filter	Cross-section	-	Filter	Cross-section	-
		Cross-section	CS1 - Tube (70;	10) 🔽	Cross-section	CS2 - Tube (50; 8)	-
		Values	un.check	-	Values	un.check	-
		Extreme	Member	-	Extreme	Member	-
		Output	Brief	-	Output	Brief	-
		Section	All	-	Section	All	-

Refresh the document to see if all the data are correctly loaded and close the window by the red cross in the top right corner.

It is wise to type a name of both documents so that they could be better recognized later. "IN" and "OUT" is the simplest possibility and it works well.

4. Optimizing tool

Scia Engineer Optimizer is a part of standard setup version. It means that it is installed on your computer together with Scia Engineer. You will find it in the particular folder under **Start > All programs > Scia Engineer**, or you may have an icon on your desktop. However, Optimizer can be launched also from the program files folder, e.g.:



c:\Program Files\SCIA\Engineer2011.0\Eot.exe.

The user interface looks similar to Scia Engineer. There is the main tree on the left with 6 functions that manage everything from model loading to results checking. These 6 steps will be described in the following chapters of this tutorial. There is also a special window with variables on the right and a few icons on top. These icons can be used to create a new EOT project, open an existing project or save the current project.

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4.1 Scia Engineer project link

In the first step you have to link EOT with a project file made in Scia Engineer. At the top there is a field for the path to the **.esa* file. Use the yellow "open folder" button to open an explorer and search for the project.

🔰 Scia Engineer project link	
Function Scia Engineer Project File C:\Users\ippodval\Documents\ESA11\project\Steel truss gr	Analysis Settings
XML Input Document	Use Auto Design:
XML Output Document	
Load Input/Output Parameters	

If necessary wait a few second to initiate the Scia Engineer project file.

Once the project is loaded, the input and output documents are ready to be selected from the list of available XML documents. Usually, only the output document has to be switched as it is the second one from the offer.

Scia Engineer project link	
Scia Engineer Project File	Analysis Settings
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XML Input Document	Use Auto Design:
n 🔹	♥ 01
XML Output Document	
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Load Input/Output Parameters	

Select the right input and output document and click the button below called **Load Input/Output Parameters**. Wait a few seconds again until all parameters are displayed in the table (and in the right panel as well).

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Xight Input Parameters Scia Engineer Name User Name Scia Engineer Type Intial Value Size User r1 r1 length 25E-00 Image: Contract of the state	Load Input/Outpr	d Parameters					he black min
X _{int} Input Parameters Volume_max Scia Engineer Name User Name Scia Engineer Type Intial Value Scia Use Her Volume_min z1 z1 Length 2.55±00 If He Length_max He Length_max z2 z2 Length 2.55±00 If He Length_max He Length_max z3 Length 2.55±00 If He Length_min He Length_max		our de bring de a					
Value Volume_min Scia Engineer Name Value Scia Engineer Name Scia Engineer Type Initial Value Size Initial Value <td< th=""><th></th><th></th><th></th><th></th><th></th><th></th><th></th></td<>							
Scia Engineer Name User Name Scia Engineer Type Intial Value Size User Houme_min z1 z1 Length 2.55=00 Image: Scia Engineer Name User Houme_min z1 z1 Length 2.55=00 Image: Scia Engineer Name Houme_min z2 z2 Length 2.55=00 Image: Scia Engineer Name Houme_min z3 z3 Length 2.55=00 Image: Scia Engineer Name Houme_min							He Surface_max
still still Sel/Desel AI IPU Unitmass_min z1 z1 Length 2.5E=00 V IPU Length_max z2 z2 Length 2.5E=00 V IPU Length_max z3 z3 Length 2.5E=00 V IPU Length_max							Surface_max Surface_min Volume_max
z1 Length 2.5E+00 V Helength_max z2 z2 Length 2.5E+00 V Helength_max z3 z3 Length 2.5E+00 V Helength_min	X _{al} Input Parameters	🖡 Output Parameter	Scia Engineer	ype Initial Value	Size	Use	⇔ Surface_max ⇔ Surface_min ⇔ Volume_max ⇔ Volume_min
12 12 Length 25€+00 V → Length_min	X Input Parameters	🖡 Output Parameter	Scia Engineer	ype Initial Value	Size		Surface_max Surface_min Volume_max Volume_min Volume_min Unitmass_max
	Zigi Input Parameters Scia Engineer Name	User Name					be Surface_max be Surface_min be Volume_max be Volume_min be Unitmass_max be Unitmass_min
	Zigg Input Parameters Scia Engineer Name	Ze Output Parameter User Name 21 22	Length	2.5	E+00 E+00	Sel/Desel All	Burface_max Surface_min Burface_min Wolume_min Unitmass_max Unitmass_min Hength_max
	Zig Input Parameters Scia Engineer Name	Ze Output Parameter User Name 21 22	Length Length	2.5	E+00 E+00	Sel/Desel All	Surface_max Surface_min Surface_min Volume_max Volume_max Volume_min Unitmass_max Unitmass_min Length_max Unitvolumemass_m
	Zigg Input Parameters Scia Engineer Name	Ze Output Parameter User Name 21 22	Length Length	2.5	E+00 E+00	Sel/Desel All	Surface_max Surface_min Surface_min Volume_max Volume_max Volume_min Unitmass_max Unitmass_min Length_max Unitvolumemass_m Unitvolumemass_m
₩ Univolumenass_m ₩ dx.max ₩ dx.min	Zigg Input Parameters Scia Engineer Name	Ze Output Parameter User Name 21 22	Length Length	2.5	E+00 E+00	Sel/Desel All	Buface_max Sufface_min Sufface_min Volume_max Volume_max Unitmass_max Unitmass_max Unitmass_min Length_max Unitvolumemass_m Unitvolumemass_m dt_max

At this point new files are automatically generated in the folder where the project is saved. The files are related to the input and output XML documents and two files are created for both of them *_in.xml *_out.xml *_in.xml.def *_out.xml.def

The middle part of the screen shows also the available types of **Analysis Settings**. Leave the default Linear Calculation option selected in the combo-box.

Function	Analysis Settings	
Ga Engineer Project File C:\Users\ipodval\Documents\ESA11\project\Steel truss gir 🥁	Linear Calculation	-
XML Input Document	Use Auto Design:	
n 🔻	V 01	
ML Output Document		
out 🔹		

If any autodesign item has been created in the used Scia Engineer project it will be listed in the white box here. Tick the items you want to be included in the optimization procedure. We want to design all cross-sections in Scia Engineer, thus tick the *O1* Autodesign.

👼 Scia Engineer project link	
Function Scia Engineer Project File	Analysis Settings
C:\Users\godval\Documents\ESA11\project\Steel truss gr	Linear Calculation 💌
XML Input Document	Use Auto Design:
in •	Ø 01
XML Output Document	
out	
Load Input/Output Parameters	

4.2 Formulas

The Scia Engineer Optimizer is a scientific tool where you don't have to fully rely on what have been programmed but where you can add your own formulas. At the beginning of the text editor for formulas there is a paragraph with hints and instructions about how this environment can be used. There is also a list of supported functions.

```
💋 Formulas
    2 // Use directive on start line:
    3 // const - For constant variable
4 // var - This variable can be optimised
    5// without directive - dependent variable,
    6 // Esa input parameters can be defined as dependent
    7 // Characters after // are ignored, use for any notice
    8 // Environment is case sensitive !!
    9 // Suported function:
   10 // abs, max, min, average, sin, cos, tan, tg, arcsin, asin, arccos, acos
   11 // arctan, atan, arctg, arctan, ln, log, exp, sign, sgn, sqrt, int, floor
   12 // ceil, frac, not // goniometric function are in radians
   13// Predefined constant: M_PI,M_E,M_SQRT2
   14//
   15 // Example:
   16//
   17 // const a = 2.321
   18// var b = -4.564e-5 // value for initialize
   19// c = a + b
   20 // d = c^3 + \ln(a) + \max(a;b;c)
   21 // Esa_Input_1 = c * sin(M_PI*d/180) // OK
   22// cost = 45 * Esa_Otput_1 + 45.35 * Esa_Output_2
23// Esa_Input_2 = 2 * cost // !! Error !! Cyclic Dependency
   24// See Environment Help for more inforamtion
   26 // Place here your user Function:
   27
< III
=== Formulas are OK ===
۰
```

However, the whole step is optional. We won't be dealing with it in this tutorial.

4.3 **Optimization analysis**

In the third step the optimization analysis is set. Variables, constraints and objective are selected and the type of strategy is chosen.

All **independent variables** ticked in the input parameters are displayed in the first tab. Please, pay attention to their minimum and maximum values to keep the design inside reasonable boundaries. Any variable can be set as constant; basically it is the

same as omitting it. We decided to remain the top level of the girder, thus z3 is constant.

Optimization an	alysis	_		_	_	
🔏 Independent Variables	💘 Optimization					
User Name	Initial Value	Minimum	N	Maximum	Step	Constant
z1	2	2.5E+00	1.E-03	2.5E+00	0.	
z2	2	2.5E+00	1.E-03	2.5E+00	0.	
z3		2.5E+00	2.5E+00	2.5E+00	0	v

The Optimization tab requires more settings - all related to the analysis itself:

ψ	Ор	timization analysis	_	_	_	
4	×,	Independent Variabler 💘 Optimizati	on			4
Тур	e of S	trategy				
Nel	der-Mea	d strategy 🔹	Strategy settings	3		
[mini	jective ^{imize :} nstrain	Mass_max	RUN			
1	1	seccheck_max		<=	1	
2	-	stabcheck_max		<=	1	
3	3	seccheck_max_2		<=	1	
4	4	stabcheck_max_2		<=	1	
•	•			<=		

Type of strategy

There are 5 strategies implemented in EOT. Each strategy has its own specifications and is suitable for different examples. Sometimes it is necessary to test more strategies, but the detailed discussion about the selection of the strategies is out of scope of this tutorial. For our example select the heuristic method called Nelder –Mead strategy.

Strategy settings

This button enables advanced users to adjust the properties of the selected strategy. Leave the defaults.

Objective

The intention of the whole optimization is specified

here. There are two extremes that can be determined – maximum or minimum. Type a variable name from the list of dependent variables (see the right stripe of the window) into the white field.

Constraint

There may be some restrictions for the optimization. In our case we want to design the structure with respect to code regulations. The unity check of all members has to be lower than 1.0. There are two cross-sections and for both of them the section check and the stability check is considered. There are four constraints in total: the name is taken from the list of variables and the condition set is *smaller or equal to 1*.

The control in the bottom window tells us if all criteria are all right.

When ready, click button !! RUN !!

Nelder-Mead strategy Gradient method - SQP Modified Simulated Annealing Diferential Evolution Nelder-Mead strategy One Parametric - Golden Section

Noldor	-Mead strategy
Merder	-meau suategy
Property	Value
Max. Iteration	100
Abs. tolerance F	1.00e-003
Abs. tolerance x	1.00e-003
p0	-2.00e-002
alfa	5.00e-002
beta	2.00e+000
К	1.00e+000

4.4 User Solution

The user can use his own independent variables and calculate the objective and other dependant variables anytime before or after the optimization. Fill in the white fields in the table and click the **Resolve** button to run the calculation, if desired.

🗐 U	ser	Solution)	_	_	_	_	_	_	_		
	Resolv	e										
Save P	oject	Delete		z1	z2	z3	_objective	constrain_1	constrain_2	constrain_3	constrain_4	Mass_max
		Delete All										
Save	As	Delete	1	1.5E+00	2.3E+00	2.5E+00	229.832E+00	-804.218E-03	-24.1081E-03	-196.422E-03	2.57287E+00	229.832E
Save	As	Delete	2	1.4E+00	2.6E+00	2.5E+00	288.218E+00	-795.583E-03	-337.65E-03	-313.838E-03	1.78433E+00	288.218E
			•									
						/hen the and res						o appl

4.5 **Optimization in progress**

During the optimization only the current step in the left menu is available. The iterations can be monitored in the main window under the **Optimization report** tab.

	Ø Optimization in progress	
cia Engineer project link	4 Optimization report 🗎 All Solutions	
(())	Start Optimization Strategy: Nelder-Mead strategy - initialization successful	
Formulas	Solve base of simplex	
\mathbf{A}	Iter objective tolF tolx	
Optimization analysis	1 520.8 1.70e+308 1.70e+308 Expansion	
	2 412.7 1.14e+002 1.87e-001 Expansion	
	3 406.3 1.12e+001 3.44e-001 Expansion	
User Solution	4 401.6 5.18+001 5.47e-001 Internal_contraction	
	5 399.8 4.70e+001 3.40e-001 Reflection	
111	6 385.3 4.52e+001 3.40e-001 Expansion	
ptimization in progress	7 354.5 7.44e+001 6.42e-001 Reflection	
pullization in progress	8 343.8 4.35e+001 6.42e-001 Internal_contraction	
- -	9 314.6 3.29e+001 3.40e-001 Internal_contraction	
	10 311 3.66e+000 1.88e-001 Reflection	
Result	11 3.72e+004 3.35e+000 1.88e-001 Reduction	
	12 308.4 3.69e+004 9.42e-002 Reduction	
	13 308.2 1.86e+001 4.71e-002 Internal_contraction	
	14 308.3 1.85e+001 4.66e-002 Reduction	
	15 308.3 1.86e+001 2.33e-002 Internal_contraction	

There is also a second tab with **All solutions** the number of which increases during the calculation.

3	🥢 Oj	otimizatio	on in pro	gress									
cia Engineer project link	4	O ptimization	repor 🗎 A	II Solutions									Þ
		objective	z1	z2	z3		constrain_1	constrain_2	constrain_3	constrain_4	Mass_max	Mass_min	Surfac *
	1	524.413E+00	2.5E+00	2.5E+00		2.5E+00	-884.594E-03	-307.852E-03	-817.222E-03	-307.852E-03	524.413E+00	345.958E+00	8.52
Formulas	2	412.712E+00	2.37505E+00	2.5E+00		2.5E+00	-858.439E-03	-40.1254E-03	-772.972E-03	-40.1254E-03	412.712E+00	277.549E+00	7.51
₩.	3	520.813E+00	2.5E+00	2.37505E+00		2.5E+00	-877.582E-03	-292.501E-03	-808.75E-03	-292.501E-03	520.813E+00	346.188E+00	8.45
Ψ.	4	409.78E+00	2.37505E+00	2.37505E+00		2.5E+00	-850.961E-03	-17.9714E-03	-761.682E-03	-17.9714E-03	409.78E+00	277.549E+00	7.44
ptimization analysis	5	406.332E+00	2.31257E+00	2.31257E+00		2.5E+00	-847.241E-03	-39.7656E-03	-761.101E-03	-39.7656E-03	406.332E+00	276.288E+00	7.38
	6	405.255E+00	2.18762E+00	2.43752E+00		2.5E+00	-857.745E-03	-123.492E-03	-783.988E-03	-123.492E-03	405.255E+00	273.738E+00	7.37
	7	401.559E+00	2.03144E+00	2.46876E+00		2.5E+00	-856.619E-03	-201.905E-03	-802.069E-03	-201.905E-03	401.559E+00	271.098E+00	7.30
User Solution	8	394.857E+00	1.96896E+00	2.28134E+00		2.5E+00	-849.508E-03	-195.958E-03	-790.373E-03	-195.958E-03	394.857E+00	269.487E+00	7.16
11	9	354.532E+00	1.76592E+00	2.17201E+00		2.5E+00	-839.657E-03	-240.543E-03	-730.352E-03	-146.727E-03	354.532E+00	265.95E+00	6.63
///	10	229.946E+00	1.48478E+00	2.32819E+00		2.5E+00	-805.459E-03	-30.654E-03	-223.382E-03	1.6461E+00	229.946E+00	207.693E+00	4.98
timization in progress	11	281.285E+00	1.07088E+00	2.336E+00		2.5E+00	-825.055E-03	-240.332E-03	-508.133E-03	-240.332E-03	281.285E+00	259.755E+00	5.37
ann progress	12	399.771E+00	2.10563E+00	2.31648E+00		2.5E+00	-850.295E-03	-140.975E-03	-780.244E-03	-140.975E-03	399.771E+00	272.027E+00	7.26
	13	355.894E+00	1.69173E+00	2.32429E+00		2.5E+00	-854.6E-03	-317.984E-03	-764.178E-03	-317.984E-03	355.894E+00	265.318E+00	6.67
	14	385.348E+00	1.84011E+00	2.01972E+00		2.5E+00	-828.856E-03	-200.598E-03	-775.819E-03	-200.598E-03	385.348E+00	267.442E+00	6.97
Result	15	378.591E+00	1.74444E+00	1.7952E+00		2.5E+00	-806.773E-03	-190.693E-03	-757.579E-03	-190.693E-03	378.591E+00	266.789E+00	6.82

The bottom status bar shows the progress, total time, average time per one solution and there are also two important buttons for pausing or stopping the optimization.

Number of Scia Engineer 53 Time : 14:49 Avg. time	per solution : 00:16.6 Pause Stop
---	-----------------------------------

4.6 Result

If the optimization is successful, no signal appears at the end.

There are three tabs in results which offer different outputs.

The **Optimization Protocol** shows information about iterations and you can study the progress of the optimization. At the end there is also a note about the completion and total calculation time.

<i> </i> Res	ult		
ه 🚺 د	Optimization Protocol	K Best Solutions All Solutions	٥
34	289.3	1.34e-002 7.75e-004 Expansion	
35	289.3	2.13e-002 1.35e-003 Internal_contraction	
36	289.3	1.35e-002 1.27e-003 Internal_contraction	
37	289.3	1.16e-002 1.27e-003 Reflection	
38	289.3	1.13e-002 1.27e-003 Internal_contraction	
39	289.3	6.04e-003 7.47e-004 Internal_contraction	
40	289.3	3.44e-003 4.88e-004 Internal_contraction	
41	289.3	2.41e-003 4.55e-004 Internal_contraction	
42	289.3	1.63e-003 4.55e-004 Expansion	
43	289.3	2.50e-003 7.65e-004 Expansion	
44	289.3	4.87e-003 1.29e-003 Expansion	
45	289.3	8.07e-003 2.18e-003 Expansion	
46	289.3	1.40e-002 3.67e-003 Internal_contraction	
47	289.3	9.60e-003 2.42e-003 Expansion	
48	307.9	1.43e-002 3.43e-003 Reduction	
49	307.9	1.86e+001 1.72e-003 Reflection	E
50	307.8	1.86e+001 1.72e-003 Reflection	
51	307.8	1.86e+001 1.72e-003 Reduction	
52	307.9	1.86e+001 8.58e-004 Reduction	
53	307.9	1.86e+001 4.29e-004 Internal_contraction	
54	307.9	1.86e+001 4.29e-004 Reduction	
55	307.9	1.86e+001 2.14e-004 Internal_contraction	
56	307.9	<u>1.86e+001 2.14e</u> -004 Reduction	
	ation task has Strategy conve		
	ime : 48:31.3		
Average	time per solut	tion : 00:14.3	
	-		
			-

Best Solutions tab offers one or more solutions that are considered to be the best. You can save such a solution as a Scia Engineer project (Save As button) or set the calculated values as initial ones and run a new optimization (Set Initial button).

 i Resul	t	_								
۹ 🖉 Opti	imization Protoco	💥 Best Solution	s 📄 All Solu	tions						Þ
Save Project	Set initial	objective	z1 z	2	z3	constrain_1	constrain_2	constrain_3	constrain_4	Mass_max
Save As	Set initial 1	281.285E+00	1.07088E+00	2.336E+00	2.5E+00	-825.055E-03	-240.332E-03	-508.133E-03	-240.332E-03	281.285E

There are also **All Solutions** that have been found during the optimization. One can compare them or search for a solution which is not necessarily the best one but more suitable for the user. Any item can be also saved as a project or set as initial for the next optimization attempt.

i Resu	lt											
	timization Proto	ocol	💥 Best Solution	r 📄 All Sol	utions							Þ
Save Project	Set initial		objective	z1	z2	z3		constrain_1	constrain_2	constrain_3	constrain_4	Mass_m *
Save As	Set initial	1	524.413.E+00	2.5.E+00	2.5.E+00		2.5.E+00	-884.594.E-03	-307.852.E-03	-817.222.E-03	-307.852.E-03	524.41
Save As	Set initial	2	454.089.E+00	2.37505.E+00	2.5.E+00		2.5.E+00	-858.841.E-03	-69.9843.E-03	-825.812.E-03	-69.9843.E-03	454.08
Save As	Set initial	3	520.813.E+00	2.5.E+00	2.37505.E+00		2.5.E+00	-877.582.E-03	-292.501.E-03	-808.75.E-03	-292.501.E-03	520.81 =
Save As	Set initial	4	450.258.E+00	2.37505.E+00	2.37505.E+00		2.5.E+00	-854.525.E-03	-56.3482.E-03	-817.199.E-03	-56.3482.E-03	450.25
Save As	Set initial	5	446.141.E+00	2.31257.E+00	2.31257.E+00		2.5.E+00	-850.962.E-03	-78.7781.E-03	-816.791.E-03	-78.7781.E-03	446.14
Save As	Set initial	6	405.255.E+00	2.18762.E+00	2.43752.E+00		2.5.E+00	-857.745.E-03	-123.492.E-03	-783.988.E-03	-123.492.E-03	405.25
Save As	Set initial	7	401.559.E+00	2.03144.E+00	2.46876.E+00		2.5.E+00	-856.619.E-03	-201.905.E-03	-802.069.E-03	-201.905.E-03	401.55
Save As	Set initial	8	394.857.E+00	1.96896.E+00	2.28134.E+00		2.5.E+00	-849.508.E-03	-195.958.E-03	-790.373.E-03	-195.958.E-03	394.85
Save As	Set initial	9	354.532.E+00	1.76592.E+00	2.17201.E+00		2.5.E+00	-839.657.E-03	-240.543.E-03	-730.352.E-03	-146.727.E-03	354.53
Save As	Set initial	10	247.254.E+00	1.48478.E+00	2.32819.E+00		2.5.E+00	-812.173.E-03	-61.9762.E-03	-559.499.E-03	-61.9762.E-03	247.25
Save As	Set initial	11	281.285.E+00	1.07088.E+00	2.336.E+00		2.5.E+00	-825.055.E-03	-240.332.E-03	-508.133.E-03	-240.332.E-03	281.28
Save As	Set initial	12	336.036.E+00	805.366.E-03	2.03925.E+00		2.5.E+00	-820.973.E-03	12.1024.E-03	-537.992.E-03	12.1024.E-03	336.03
Save As	Set initial	13	666.009.E+00	192.33.E-03	1.82449.E+00		2.5.E+00	-420.54.E-03	-152.422.E-03	-216.476.E-03	816.488.E-03	666.00
Save As	Set initial	14	357.442.E+00	1.72492.E+00	2.36138.E+00		2.5.E+00	-855.011.E-03	-311.382.E-03	-763.773.E-03	-311.382.E-03	357.44
Save As	Set initial	15	279.106.E+00	1.11188.E+00	2.14663.E+00		2.5.E+00	-831.447.E-03	-273.507.E-03	-439.405.E-03	-273.507.E-03	279.10
Save As	Set initial	16	279.106.E+00	1.11188.E+00	2.14663.E+00		2.5.E+00	-831.447.E-03	-273.507.E-03	-439.405.E-03	-273.507.E-03	279.10
Save As	Set initial	17	336.036.E+00	805.366.E-03	2.03925.E+00		2.5.E+00	-820.973.E-03	12.1024.E-03	-537.992.E-03	12.1024.E-03	336.03
Save As	Set initial	18	500.105.E+00	416.849.E-03	2.31062.E+00		2.5.E+00	-709.05.E-03	-88.1407.E-03	-709.05.E-03	-88.1407.E-03	500.10
Save As	Set initial	19	228.245.E+00	1.42865.E+00	2.20666.E+00		2.5.E+00	-795.825.E-03	11.0937.E-03	-196.347.E-03	2.05947.E+00	228.24
Save As	Set initial	20	406.648.E+00	754.117.E-03	2.27597.E+00		2.5.E+00	-806.555.E-03	-275.061.E-03	-389.505.E-03	-275.061.E-03	406.64
Save As	Set initial	21	280.088.E+00	1.09138.E+00	2.24131.E+00		2.5.E+00	-835.307.E-03	-263.303.E-03	-514.401.E-03	-263.303.E-03	280.08
Save As	Set initial	22	320.967.E+00	1.4389.E+00	2.15932.E+00		2.5.E+00	-841.504.E-03	-377.898.E-03	-693.49.E-03	-377.898.E-03	320.96
Save As	Set initial	23	338.828.E+00	764.366.E-03	2.22862.E+00		2.5.E+00	-789.63.E-03	91.6382.E-03	-410.718.E-03	91.6382.E-03	338.82
Save As	Set initial	24	497.971.E+00	427.099.E-03	2.26328.E+00		2.5.E+00	-718.059.E-03	-102.714.E-03	-718.059.E-03	-102.714.E-03	497.97
Save As	Set initial	25	280.958.E+00	1.27027.E+00	2.17664.E+00		2.5.E+00	-833.35.E-03	-335.314.E-03	-311.659.E-03	-335.314.E-03	280.95
Save As	Set initial	26	327.655.E+00	933.E-03	2.2113.E+00		2.5.E+00	-828.307.E-03	-38.1606.E-03	-106.769.E-03	-38.1606.E-03	327.65
Save As	Set initial	27	327.655.E+00	933.E-03	2.2113.E+00		2.5.E+00	-828.307.E-03	-38.1606.E-03	-106.769.E-03	-38.1606.E-03	327.65
€ 2010 Åe	Cat initial	1 28	105 658 E±00	764 366 E.03	0 00860 E±UU		2.5 E±00	.91/ 772 E.02	.284 521 E.03	.418 015 E.03	.284 521 E.03	105.65

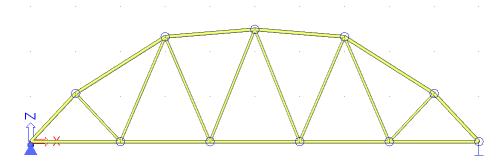
Three buttons in the bottom right corner enables the user to **Save protocol** (the same as you see on the screen, in *.*txt* format), **Save tables as CVS** or **Export** (results) **to Excel**. The last option opens Microsoft Excel with a new file containing three tabs – exactly the same as in Results of the EOT application. The advantage of such an export is that you can insert illustrative graphs to demonstrate the optimization process.

	D	E	F	G	Н		J	К	L	М	N	0	Р	Q	R	S	T	U	V	W	Х	Y	Z
1 :	2	z3	D1	D2	constrai	constrai	constrai	constrai	Mass max	seccheck	stabcheck	seccheck	stabcheck	max 2									
2	2,5	2,5	0,07	0,05	-0,88459	-0,30785	-0,81722	-0,37067	524,4128	0,115406	0,692148	0,182778	0,62933	0,692148									
3	2,5	2,5	0,07	0,05	-0,88486	-0,33755	-0,82255	-0,41363	520,8325	0,115138	0,66245	0,177453	0,586374	0,66245	_								
4	2,455	2,5	0,07	0,05	-0,88215	-0,30241	-0,81421	-0,36393	523,0602	0,117846	0,697591	0,185785	0,636071	0,697591		550	1						
5	2,5	2,5	0,0685	0,05	-0,88218	-0,27006	-0,81733	-0,36444	515,7639	0,117825	0,729943	0,182669	0,635558	0,729943			m						
6	2,5	2,5	0,07	0,049	-0,88423	-0,30471	-0,81286	-0,33394	520,1639	0,115765	0,695289	0,187142	0,666059	0,695289		500							
7	2,4775	2,5	0,06925	0,0495	-0,88247	-0,30399	-0,81626	-0,36377	515,4902	0,117531	0,69601	0,183743	0,636227	0,69601		Meight [kg] 400 350	L M	La .					
8	2,46625	2,5	0,068875	0,04925	-0,88138	-0,29074	-0,81578	-0,36663	511,0585	0,11862	0,709264	0,184224	0,633371	0,709264		₹450		11/14					
	2,473281	2,5	0,069672		-0,88276	-0,30836	-0,81566						0,637379			±		ייי יי					
	2,492441	2,5	0,069631	0,049754	-0,88409	-0,32116	-0,81898						0,613875			<u>100</u> 400							
	2,491497	2,5	0,069585	0,049348	-0,88343	-0,30602	-0,81491				0,693982					\$ 250			1161.4.	4			
12	2,480414	2,5	0,06941	0,049685	-0,88277	-0,29631	-0,8162						0,637002			> 330			WWW.	mm	~~~~~	_	
13	2,49468		0,068886		-0,88278	-0,28695	-0,8173				0,713052					300			111				
	2,476639		0,068554	0,049387	-0,88079	-0,25883	-0,81312						0,665308										
	2,470155		0,068085		-0,88009	-0,26319	-0,81631				0,736813		0,638534			250							
	2,476108		0,067597	0,049541	-0,87941	-0,24413	-0,81507				0,755865		0,653718				0	50	10	10	150	200	
	2,473955		0,066691	0,049469	-0,87765	-0,21167	-0,8145		501,5715								•	50		of iterati		200	
	2,443499		0,067602		-0,87775	-0,25143	-0,81244	-0,33761		0,122248	0,74857	0,187564	0,662386										
	2,415249		0,067153		-0,87544	-0,24168	-0,80988				0,758323												
	2,450291		0,067072		-0,87763	-0,24648	-0,81644	-0,36936			0,753522					1			1		1	1	
	2,437116		0,066331	0,049343	-0,87597	-0,22717	-0,81816	-0,3809		0,124034			0,619098			1,8							
	2,446113		0,065479		-0,87421	-0,16689	-0,81493		492,8501		0,833107	0,18507	0,650584										
	2,436044		0,063781	0,049688	-0,8703	-0,10608	-0,81455	-0,33908			0,893915		0,660925			1,6							
	2,425152		0,064118		-0,87055	-0,1254	-0,81346		480,1702										1				
	2,402651		0,062135		-0,86521	-0,04638	-0,81201	-0,31776				0,187987	0,682242			±1,4							
	2,431384		0,061867		-0,86646	-0,0277	-0,8172				0,972299		0,654234			¥12							
	2,425326	2,5		0,049807		0,089605	-0,81968				1,089605		0,652057			-1,4 y 1,2			AN IN LL				
	2,379643		0,060367		-0,86046	-0,00423	-0,8166						0,648504			÷ 1		M.A		hart	Mundar	~~~	
	2,332486	2,5	0,057205		-0,84992		-0,81789		431,9318				0,642505			2	1	1.					
	2,450377	2,5	0,06511		-0,87376	-0,15588	-0,81497				0,844115		0,658218			, ^{8′0}		•					
	2,403221		0,061948	0,04915	-0,8652	-0,06272	-0,81602	-0,34888					0,651123				M						
	2,399533		0,058534	0,049073		0,159882	-0,81185	-0,28821	448,7962				0,711787			0,6				1			
	2,380741	2,5	0,054636			0,449409	-0,80889	-0,22132	426,28				0,778685				0	50	10	00	150	200	
34	2,42772	2,5	0,064382		-0,87155	-0,1475	-0,81654	-0,35983	482,4468										Number	ofiterati	on		
	2,408929	2,5	0,060484	0,04914	-0,86178	0,061226	-0,81338	-0,31163	460,0281	0,138225	1,061226		0,688366										
	2,396444	2,5	0,061385		-0,86384	-0,06098	-0,81654	-0,3581	458,3367			0,183456		0,939018									
37	2.376644	2.5	0.060186	0.047938	-0.86033	-0.02236	-0.81782	-0.36708	445.9118	0.139668	0.977636	0.182178	0.632918	0.977636									

This result shows quite remarkable material savings, as the original mas 524 kg was finally reduced to 281,2 kg, only by means of optimization of geometry of the structure!

5. Conclusion

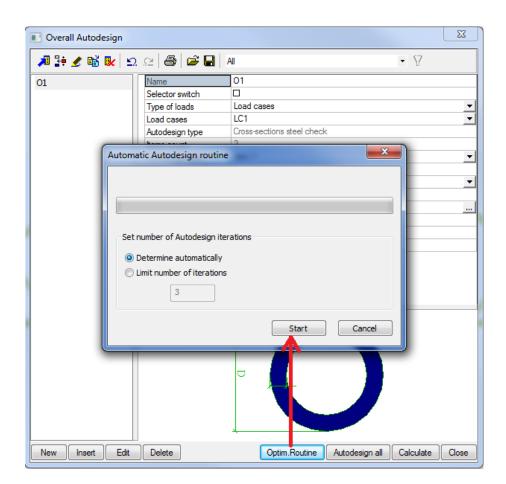
If you save the selected result using button "Save As" (see picture above) and open the saved .esa file, you will get the corresponding structure (see also attached file Steel truss girder_best.esa).



Important note:

The structure saved this way contains the status corresponding to the values of parameters. To get also correct cross-sections, it is necessary to run Autodesign function manually!

Run linear analysis and Autodesign afterwards in Scia Enigneer. Use the **Optimization Routine** for iterative design (due to reasons described in chapter 2.2). Let the software determine automatically how many iterations are necessary and click the button **Start**.



For more information, you can see the final cross-section dimensions with optimal utilization in the preview window which appears at the end of Autodesign.

Pa 🚇 📑	@ H D	100 %	- 🗹 🖬	📕 default	•
1. Routine step: 1 1.1. O1					-
Cros s-se off on	Parameter	Original oross-section	Autodesign of oross-section	Autodesign oheok [-]	
CS1 - Tube (63; 9) CS2 - Tube (19; 3)	Advanced Autodesign Advanced Autodesign	CS1 - Trubka (70; 10) CS2 - Trubka (50; 8)	CS1 - Tube (63; 9) CS2 - Tube (19; 3)	0,82 0,55	
2. Routine step: 2					
Cross-section	Parameter	Original cross-section	Autode sign of oross-section	Autode sign oheok [-]	=
Cross-se od on					
CS1 - Tube (63; 9) CS2 - Tube (19; 3)	Advanced Autodesign Advanced Autodesign	CS1 - Tube (63; 9) CS2 - Tube (19; 3)	CS1 - Tube (63; 9) CS2 - Tube (19; 3)	0,87	
CS1 - Tube (63; 9)					
CS1 - Tube (63; 9)					

Using function Bill of material you can see detailed output of mass related to each cross-section.

