OPTIMIZATION OF LOAD FLOOR SUPPORT SYSTEM

- TOPOLOGY OPTIMIZATION IN EARLY PHASE DEVELOPMENT

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INTRODUCTION – THESIS

Background

Looking to reduce weight and lead times in development

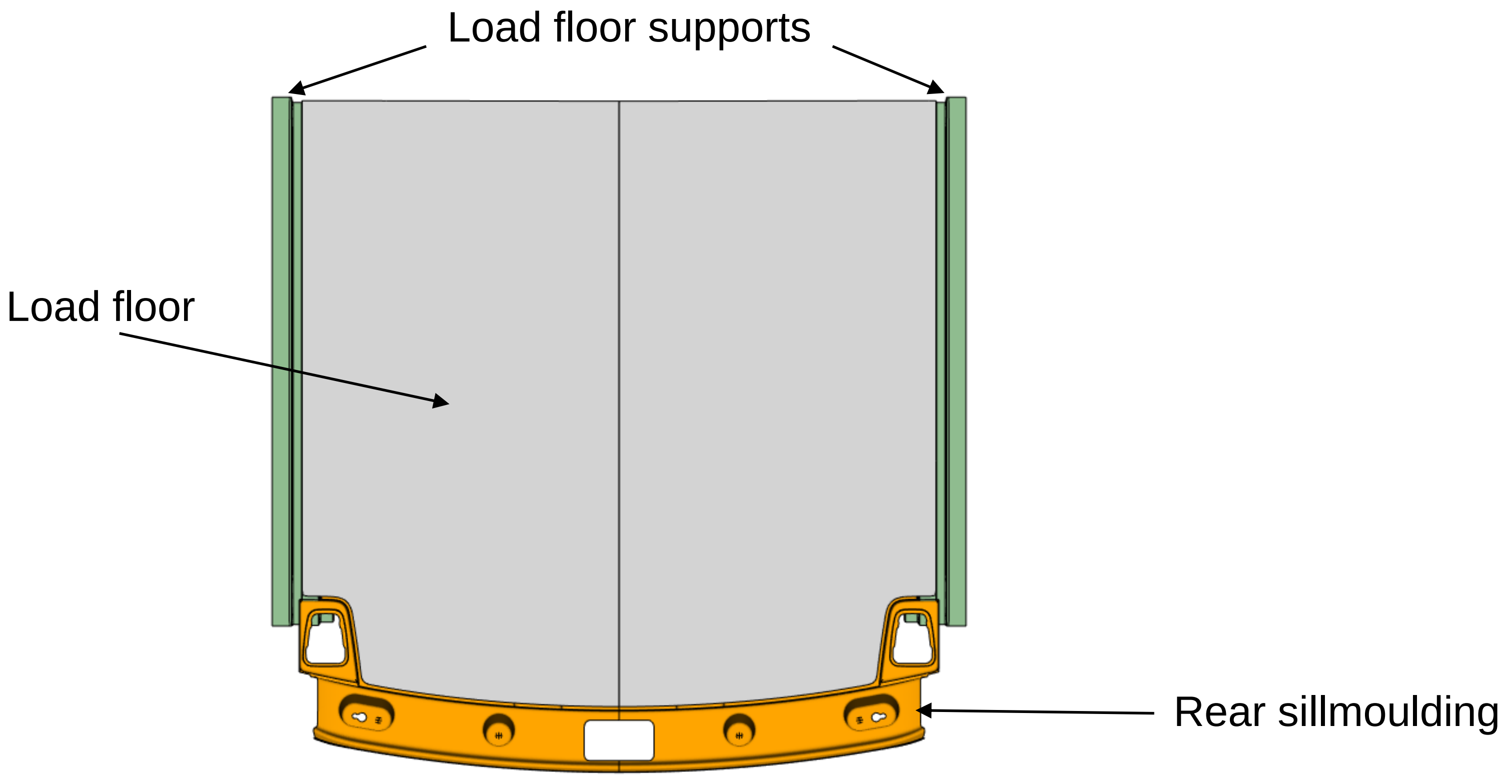
Purpose

Investigate how topology optimization can be used in early phase development at the department.

How

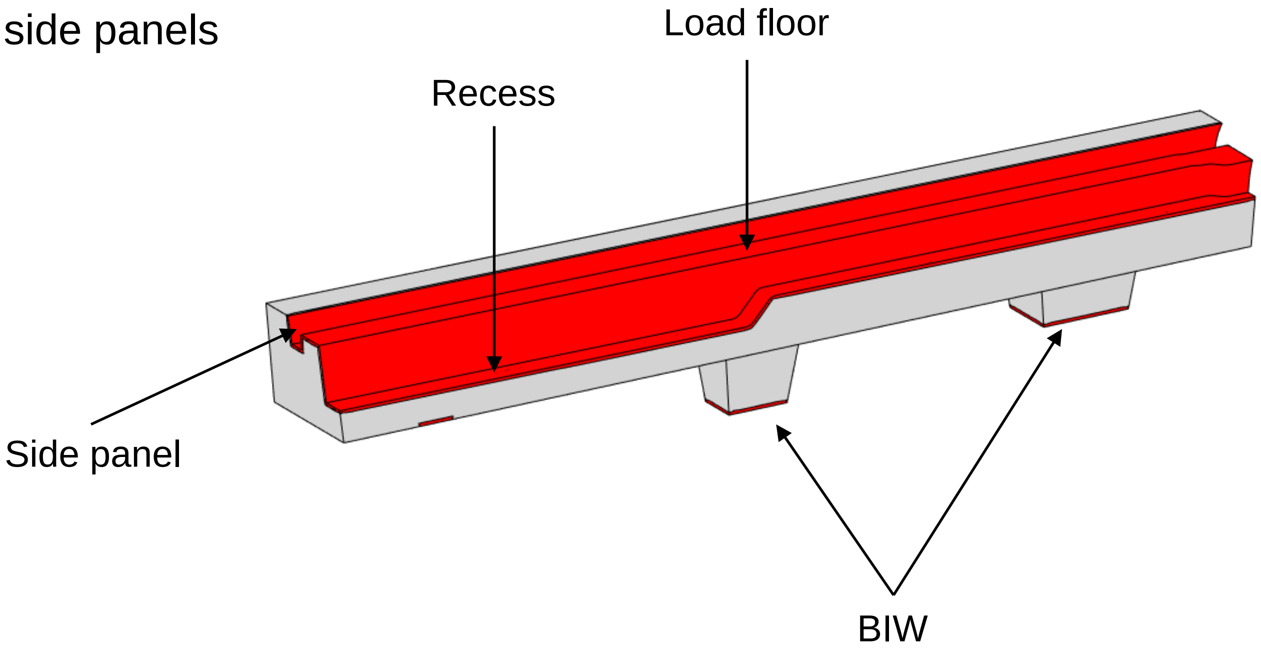
Derive a methodology for topology optimization in early phase development of the load floor supports from which lessons can be learned.

LOAD FLOOR SYSTEM



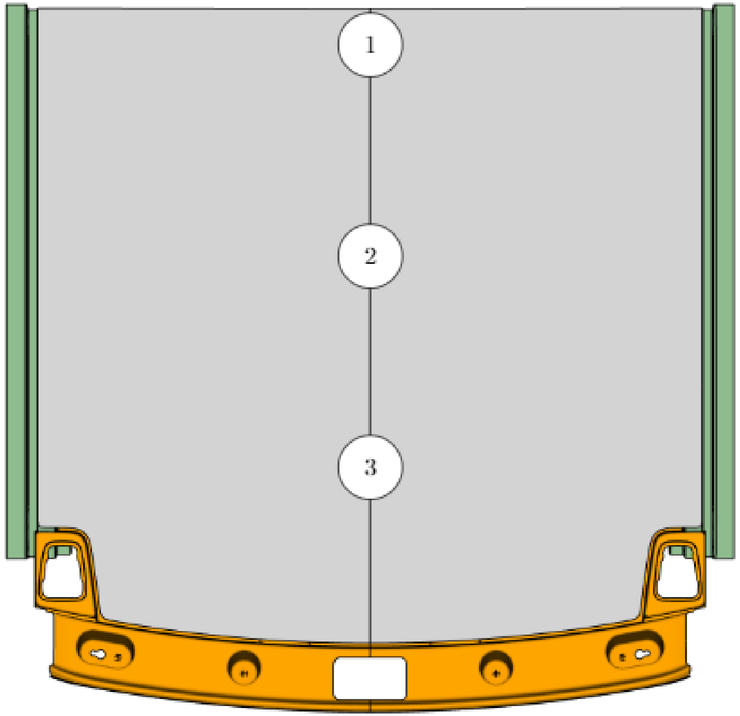
THE LOAD FLOOR SUPPORT

- Carries and distributes weight from the load floor
- Connects to BIW, load floor, side panels and a recess



LOAD CASES

- Load cases:
  - Point load placed anywhere on the load floor.
  - Distributed load on entire load floor



ADDITIONAL SUPPORT

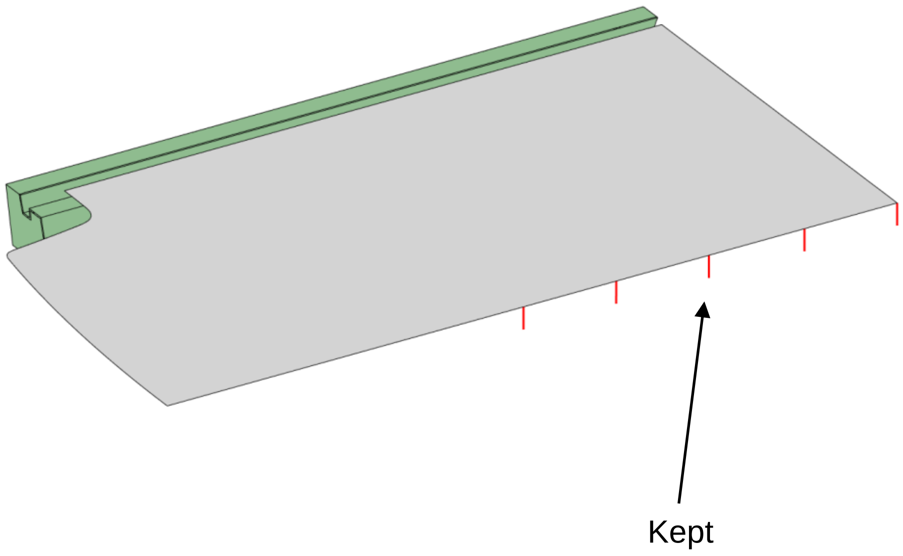
- Investigate how additional supports influence TO results.
- Performed in two steps:
  - Determine placement via TO
  - Estimate how much weight can be reduced based on displacements

Optimization setup:

Objective function: Minimize Compliance

Constraint: Volume fraction, main < 8 %,

Volume fraction, beam < 20.05 %



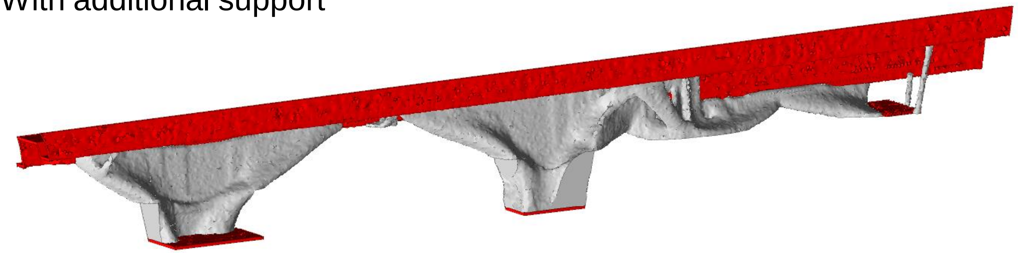
ADDITIONAL SUPPORT

Results step 1:

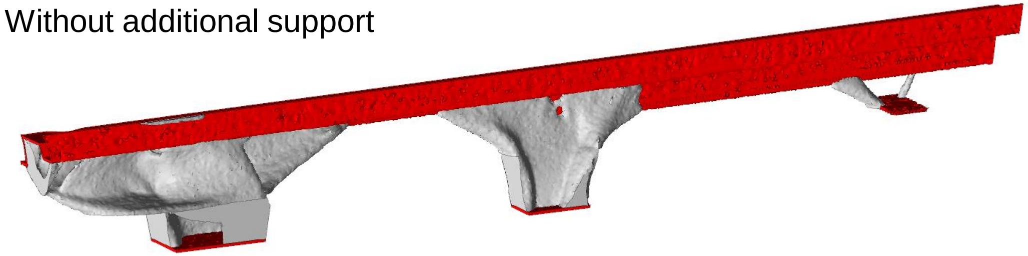
Noticeable redistribution of material.

Decrease in reaction forces & load floor displacements.

With additional support



Without additional support



ADDITIONAL SUPPORT

Second step:

Reduce main volume fraction constraint.

Significant decrease in compliance and max z-displacements of load floor support with beam.

Optimization Run	Max. z-displacement	Compliance
Reference (without support, $V_f \leq 0.024$)	-0.8449	86.9
$V_f \leq 0.024$	-0.0894	8.67
$V_f \leq 0.02$	-0.1170	9.714
$V_f \leq 0.01$	-0.1795	15.017
$V_f \leq 0.005$	-0.3355	22.168

Conclusions:

- The middle support influences material distribution.
- Reduced loading in the load floor supports could enable lower material requirements.

TRIAL CASES

Investigation of how topology optimization should be performed, how to work with volumes, design surfaces and parameters with the objective of creating feasible concepts.

Several trial cases were performed throughout the thesis, following are some of them.

TRIAL CASE 1

Objective:

See how maximum displacements and compliance relates to volume fraction.

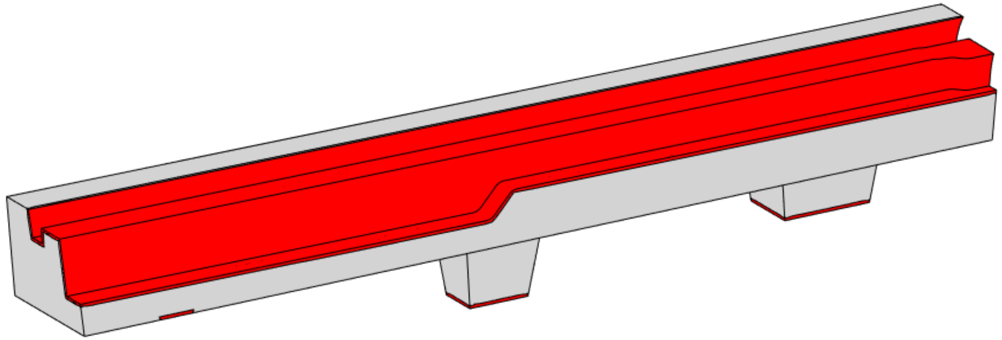
Identify areas to focus on in upcoming trial cases.

Optimization Setup:

Objective function: Minimize compliance

Constraints: Vf < 4, 3, 2, 1 and 0.5 %

draw direction in z, split tool

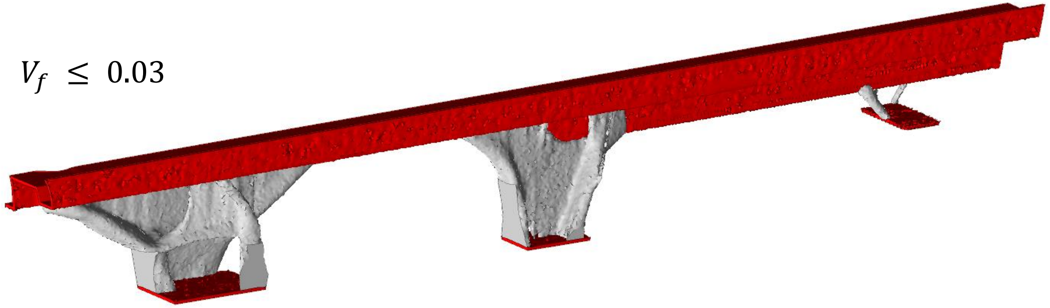


TRIAL CASE 1

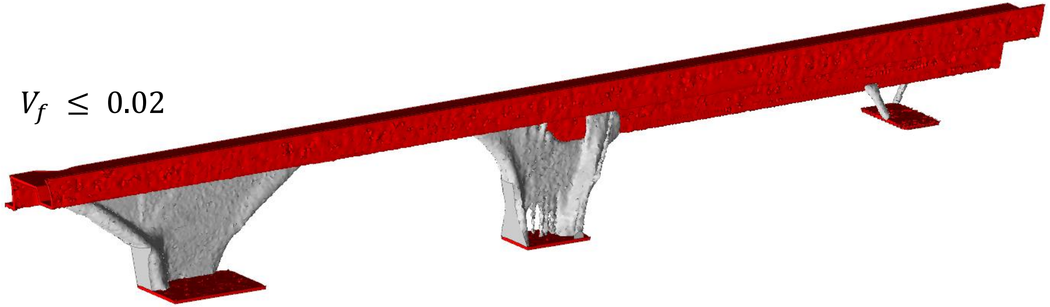
Results:

Material is heavily prioritized towards front and middle support.

$V_f \leq 0.03$



$V_f \leq 0.02$



TRIAL CASE 1

Conclusions:

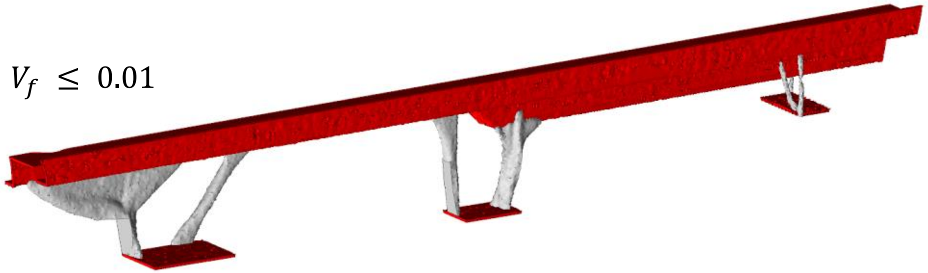
The optimization is effective at placing material where it is most needed, even at lower volume fractions.

Greater considered need to be taken towards manufacturing.

Structures < 2 % Vf proves unfeasible.

Optimization Run	Max. z-displacement	Compliance
$V_f \leq 0.04$	-0.324	52.21
$V_f \leq 0.03$	-0.560	71.13
$V_f \leq 0.02$	-0.914	97.20
$V_f \leq 0.01$	-1.069	115.63
$V_f \leq 0.005$	-3.08	177.99

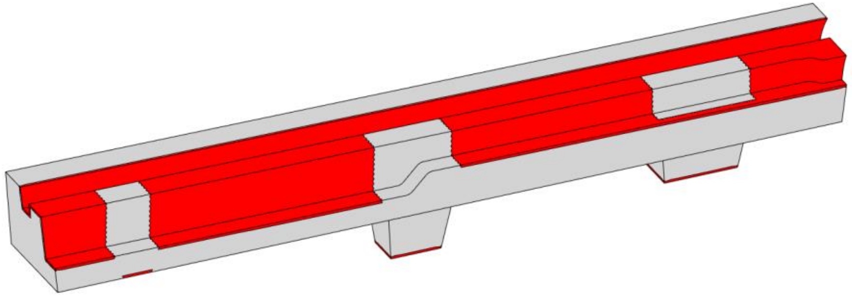
$V_f \leq 0.01$



TRIAL CASE 2

Objective:

See how changes can be introduced to the non-design volume to increase manufacturability.



Optimization Setup:

Objective function: Minimize compliance

Constraints: Vf < 5, 4, 3, 2, 1 %

draw direction in z, split tool

TRIAL CASE 2

Results:

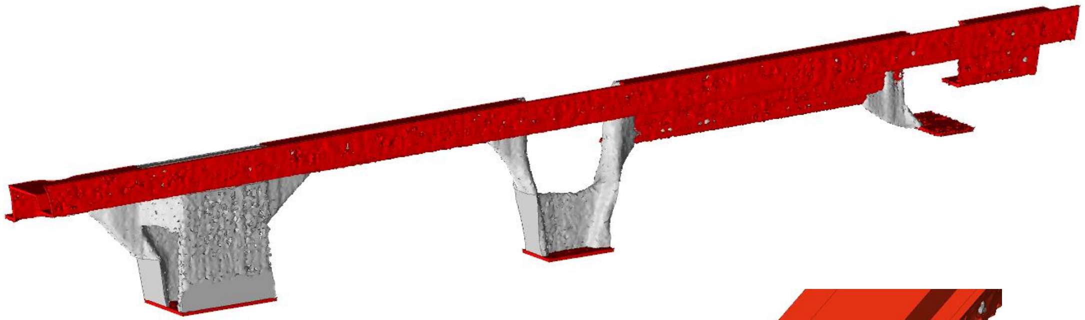
Majority of the material is focused towards the front end of the support where loading is largest.

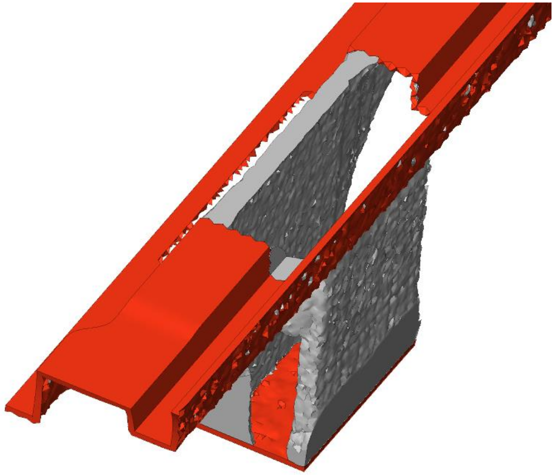
Slightly thinner sections compared to Trial case 1 are created

Conclusions:

It is noted that including parts of the non-design surface improves on manufacturability.

It is however noted that material is not prioritized to maintain the design surfaces where it is included in the design volume.



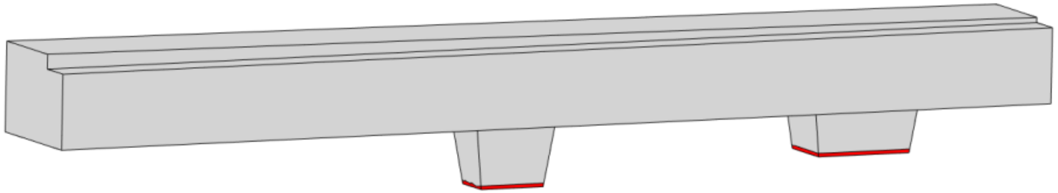


TRIAL CASE 3

Objective:

Determine whether or not it is necessary to consider the design surfaces in optimization.

If the are better alternative ways of creating the component.



Optimization Setup:

Objective function: Minimize compliance

Constraints: Vf < 6.1 %

Draw direction in z, split tool

TRIAL CASE 3

Results:

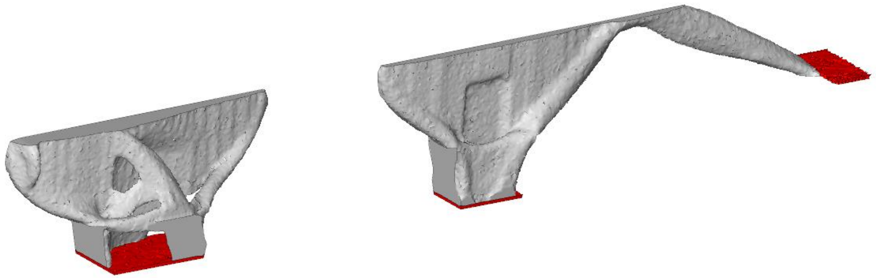
Without the design surfaces another design is created all together.

Material is heavily prioritized towards the front end.

It is unlikely that such a design can be realized into something that is useful.

Conclusions:

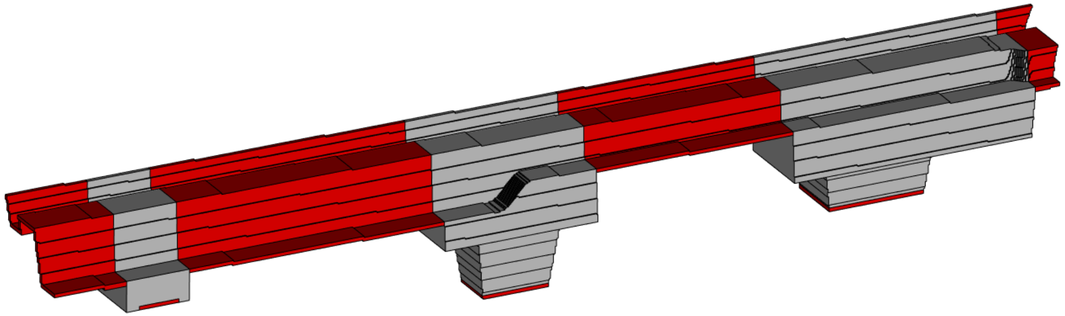
It is therefore concluded that optimization to derive concepts is not recommended without design surfaces.



TRIAL CASE 4

Objective:

See how material can be cut away to enable a finer mesh size. See if the finer mesh better depicts thin-walled structure.



Optimization setup:

Objective function: Minimize compliance

Constraint: Vf < 11 %

MAXDIM < 6

Draw direction in z, split tool

No hole

TRIAL CASE 4

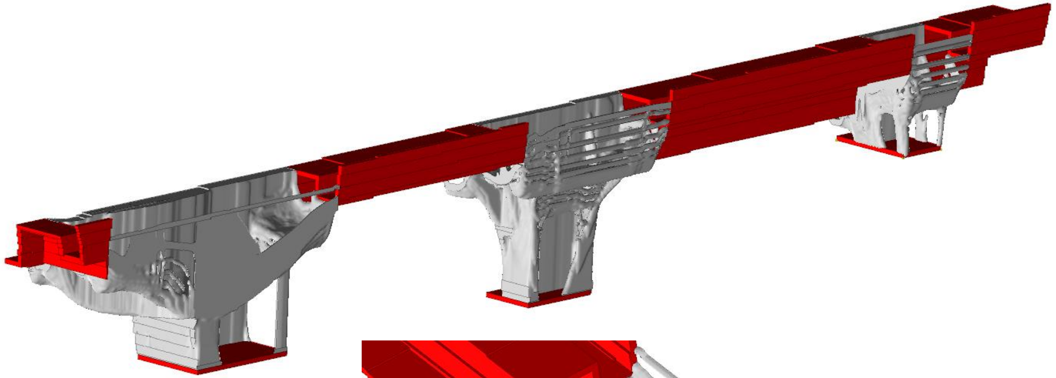
It should be noted that this trial case did not complete. However some conclusions can be drawn from it.

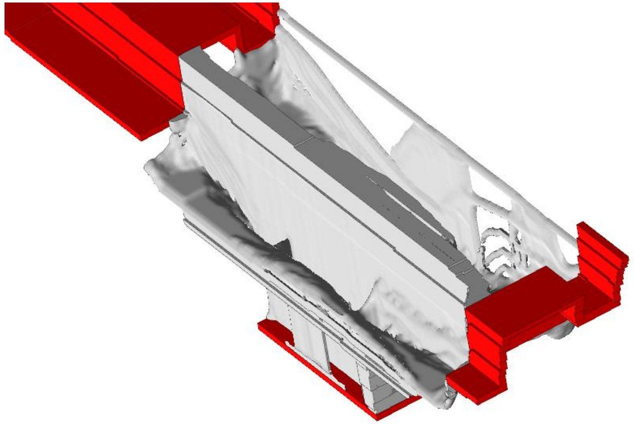
Conclusions:

The finer mesh refinement allows for thinner sections to be created.

It also shows that removing material from the initial volume could be a good idea to enable a finer mesh.

The no hole option should be used with caution as it is noted to create sections which are likely not structurally important.





TOPOLOGY OPTIMIZATION IN PRE-CONCEPT

Looking at topology optimization as a tool to help development in pre-concept stages.

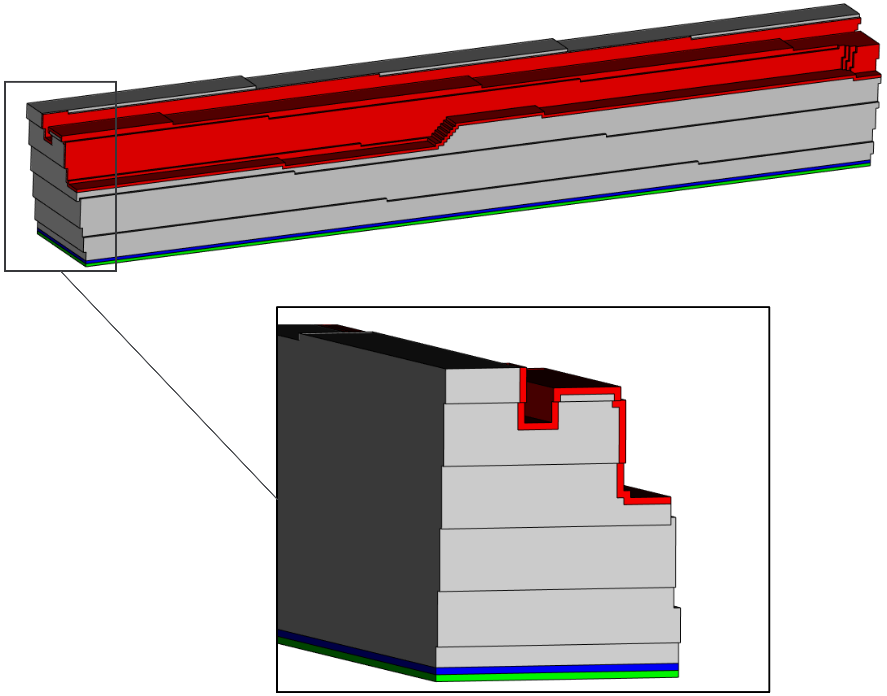
- Looking at topology optimization to determine placements of connection points.
- To get a rough estimate of the components packing volume.

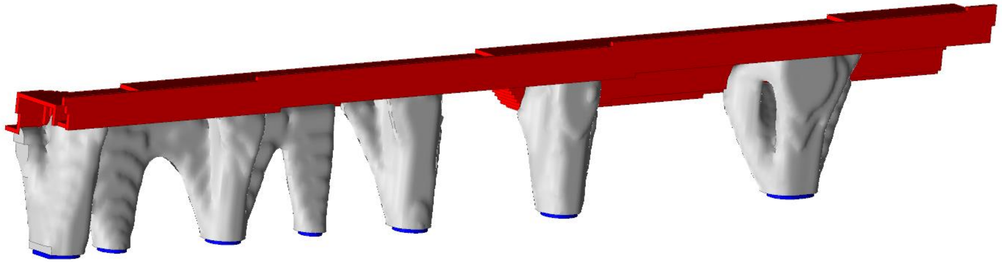
2 methods were derived and tested.

METHOD 1 – 2 DESIGN VOLUMES

Working with a modified volume where the space next to the connection points has been filled out.

Main concept of the method is to only give the interface layer a small volume fraction to derive distinct connection points.





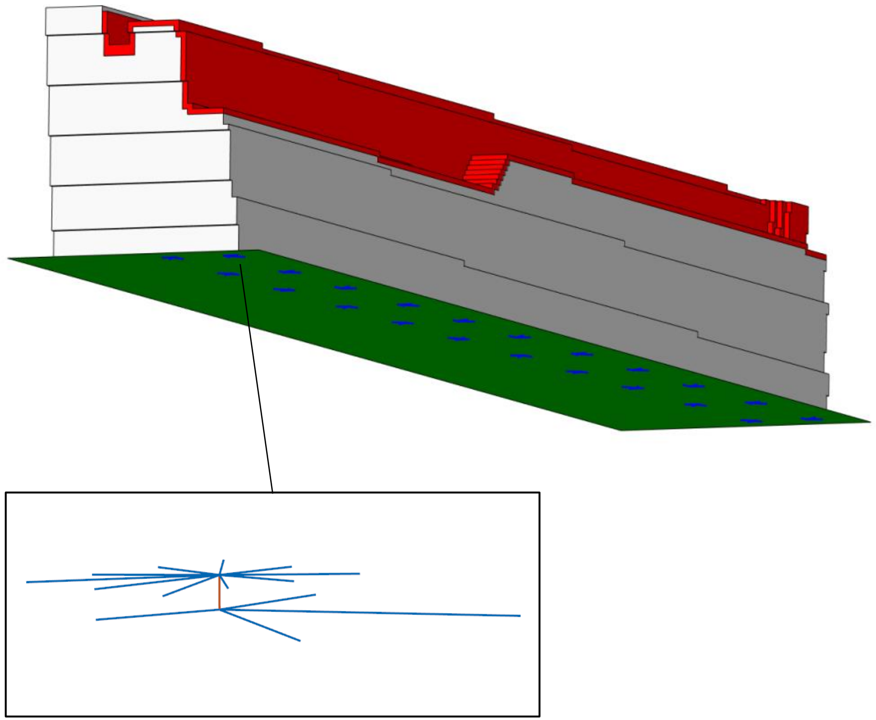
METHOD 2 – CONNECTOR ELEMENTS

Same principle idea used as in Method 1. Instead of having the entire surface to chose from it is given a select number of connectors to chose from.

Modelled with RBE3-CBEAM-RBE3, connecting the load floor support to the BIW.

Volume fraction constraint:

$$V_f \leq \frac{Desired\ number\ of\ connectors}{Total\ number\ of\ connectors} \cdot 1.05$$



METHOD 2 – CONNECTOR ELEMENTS

Optimization Setup:

Objective function: Minimize compliance

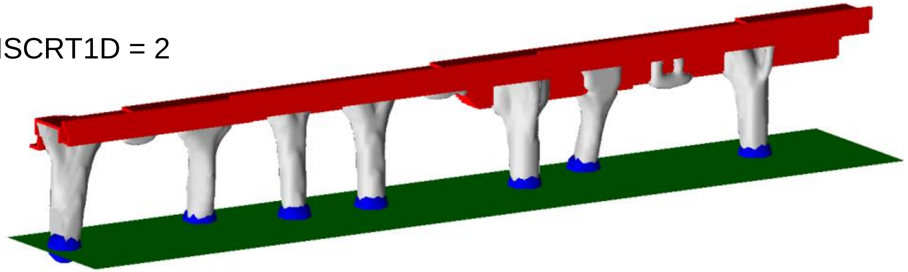
Constraint: Volume fraction, main < 3.5 %

Volume fraction, connectors < 14.35 %

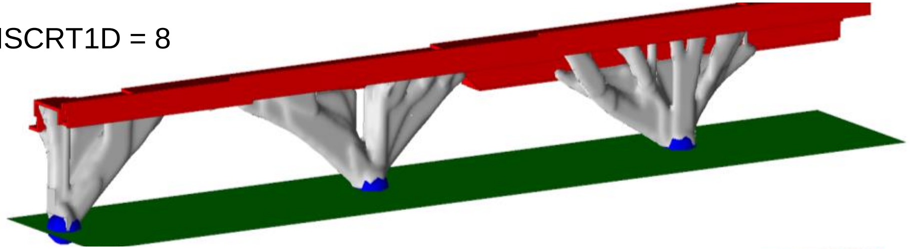
Settings: DISCRT1D, varied

An increased penalization of 1D elements helps the solution steer towards the desired number of connectors.

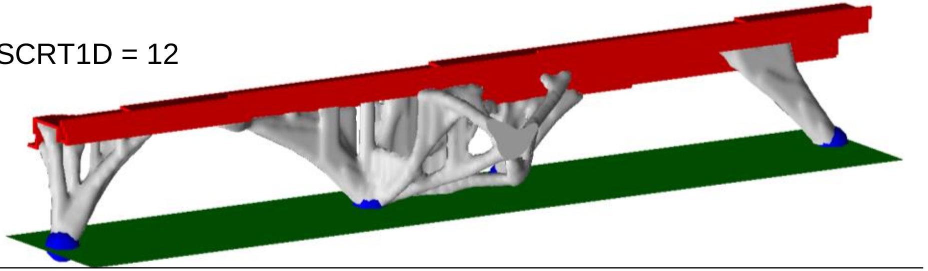
DISCRT1D = 2



DISCRT1D = 8



DISCRT1D = 12



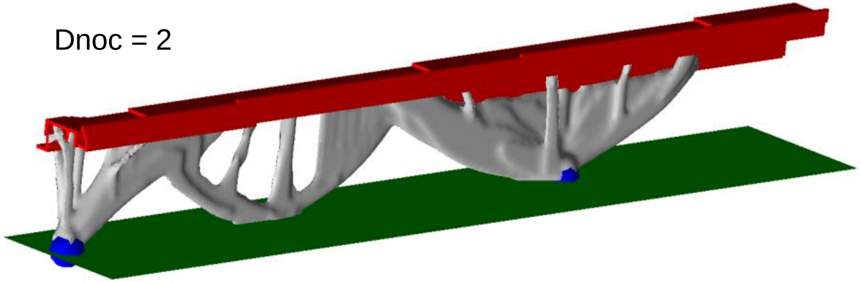
METHOD 2 – CONNECTOR ELEMENTS

Testing different number of connector left after optimization with the same material available in the main volume.

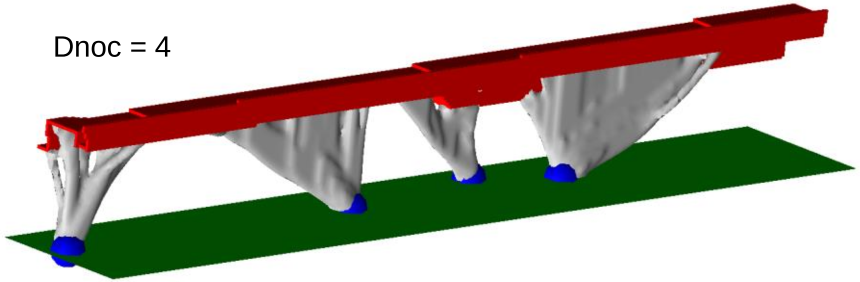
General increase in performance with more connectors kept, however not that significant.

Desired number of connectors	Max. z-displacement (mm)	Compliance
5	-0.241	125.31
4	-0.259	176.19
3	-0.363	215.12
2	-1.03	545.0

Dnoc = 2



Dnoc = 4



METHODOLOGY

From lessons learned through working with TO a methodology is suggested for giving design input:

1. Set out to define the outlying volume of the component.
2. Use previous car models as a reference to see if there is a need to add an additional support.
3. If connection point placements have not been set then use the derived method for input/evaluate different options.
4. Use the rough estimate as input for packing volume and remove material according to the original optimization model. Perform topology optimization with a higher volume fraction constraint than the target weight of the component and a fairly coarse mesh.
5. Remove material where it is least needed to further enable a finer mesh to be used in order to better be able to depict a thin-walled structure suitable for injection molding.
6. Use previous car model as a target for weight and perform several optimizations with a minimum compliance formulation and a volume fraction constraint around the target weight.

DISCUSSIONS & CONCLUSIONS

- Is topology optimization suited for the component?
- Load cases used

Conclusions:

To be used as design input rather than a prediction for weight and performance.

Topology optimization could be used in the stages prior to concept development to help give input.

FUTURE WORK

- Reducing computational effort/Finding ways of working with the finer mesh
- Study ways of enforcing uniform thickness
- Other branches of optimization

QUESTIONS?