Creating Diverse and Competitive Structural Designs via Topology Optimization

Yunzhen He, Kun Cai, Zi-Long Zhao, Yi Min 'Mike' Xie

RMIT University, Melbourne, Australia

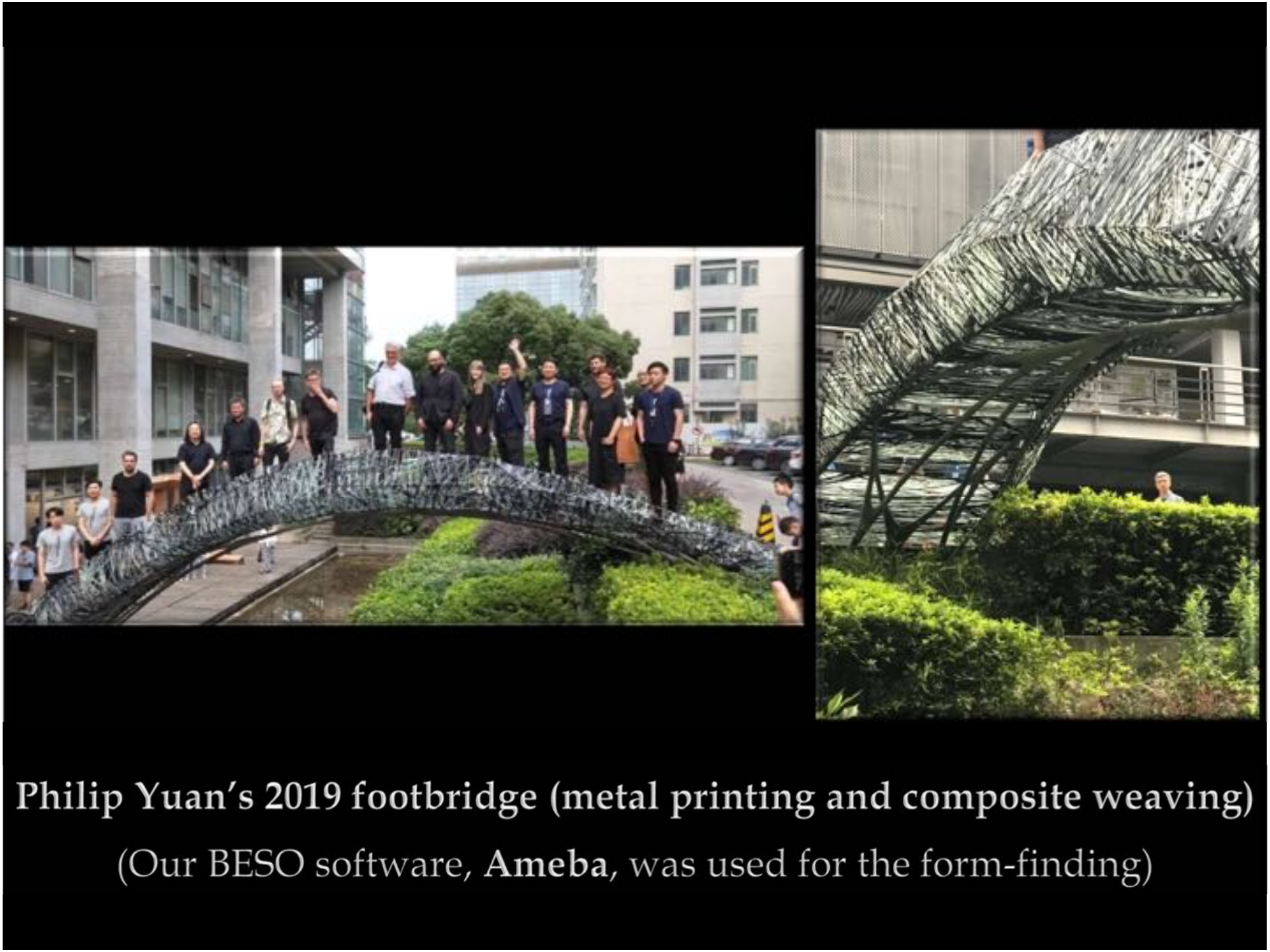
Mount Everest: *The Unique, Global Optimum*

Zhang Jia Jie:

Multiple Peaks of Similar Heights but Different Forms

How to create *diverse* and *competitive* designs without changing loading or boundary conditions?

Diverse *– topologically different*
Competitive *– structurally efficient*



Philip Yuan's 2019 footbridge (metal printing and composite weaving)

(Our BESO software, **Ameba**, was used for the form-finding)

- This study was based on the Bi-directional Evolutionary Structural Optimization (BESO) method, but most of the tactics can be applied to other optimization methods, such as SIMP, Level Set

- *ESO method* (Xie and Steven, 1993)

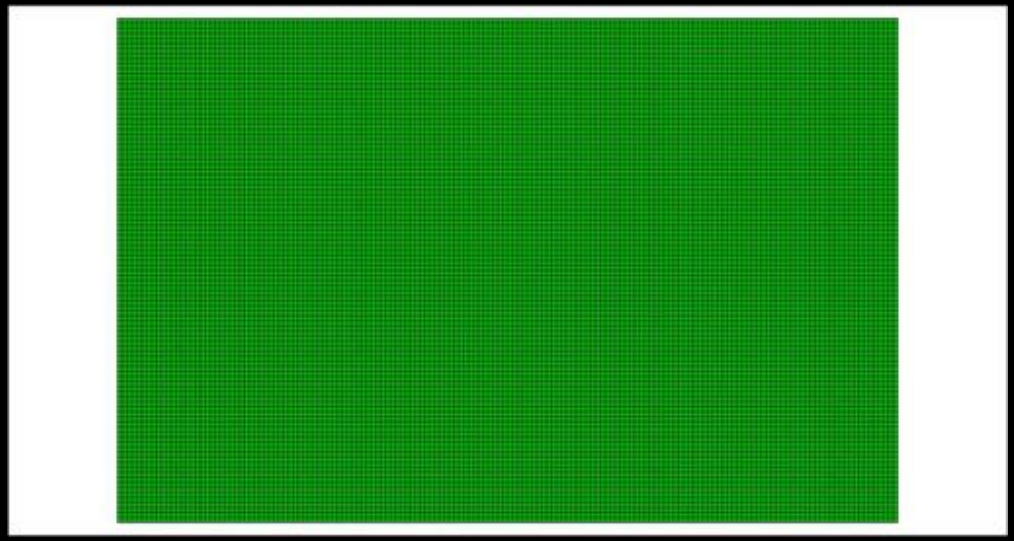
- *BESO method* (Querin, Steven, Xie 1998; Huang and Xie, 2007)

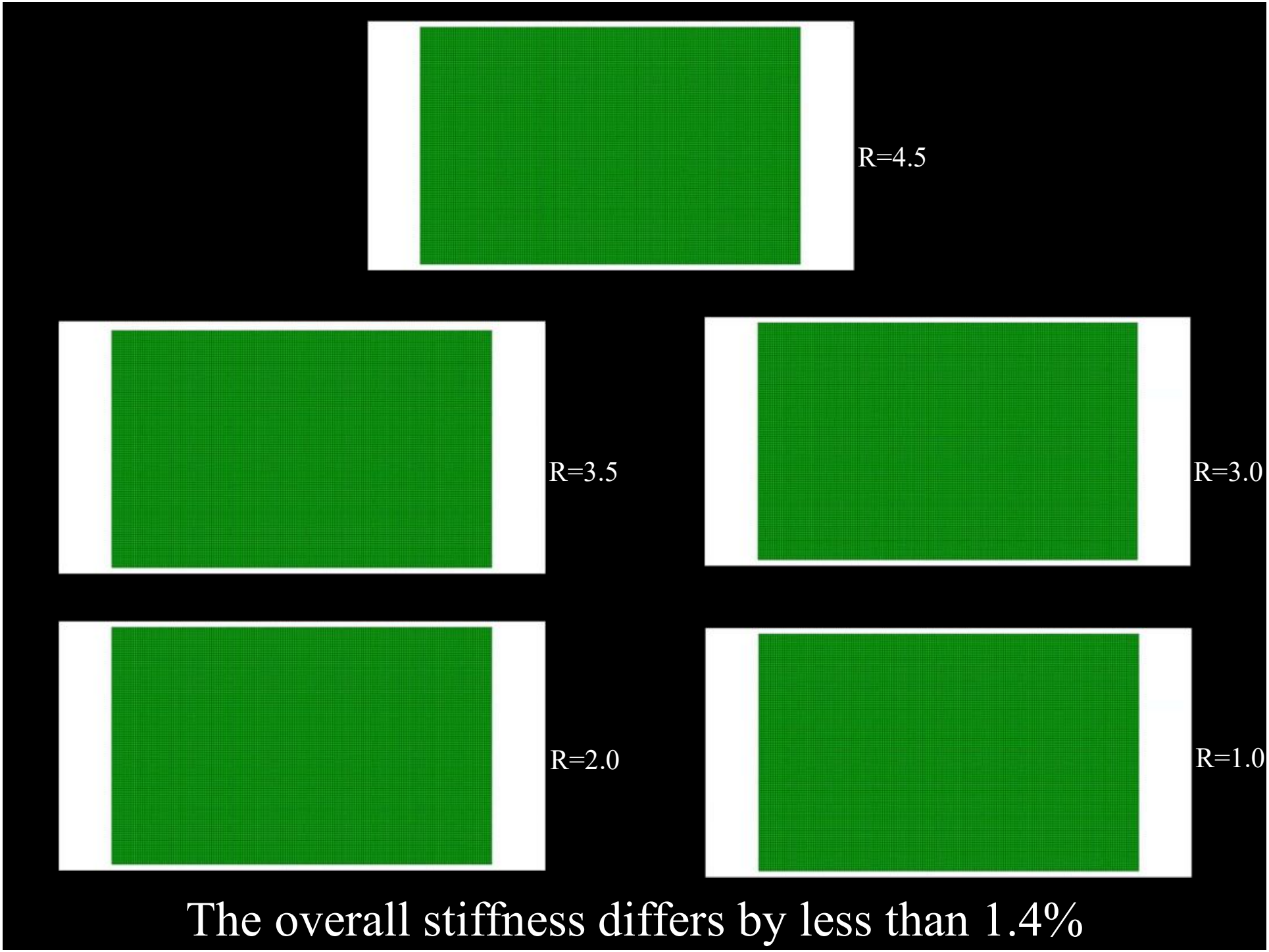
Tactic 1:

Changing parameters in the optimization algorithm


F


F




R=4.5
R=3.5
R=3.0
R=2.0
R=1.0
The overall stiffness differs by less than 1.4%

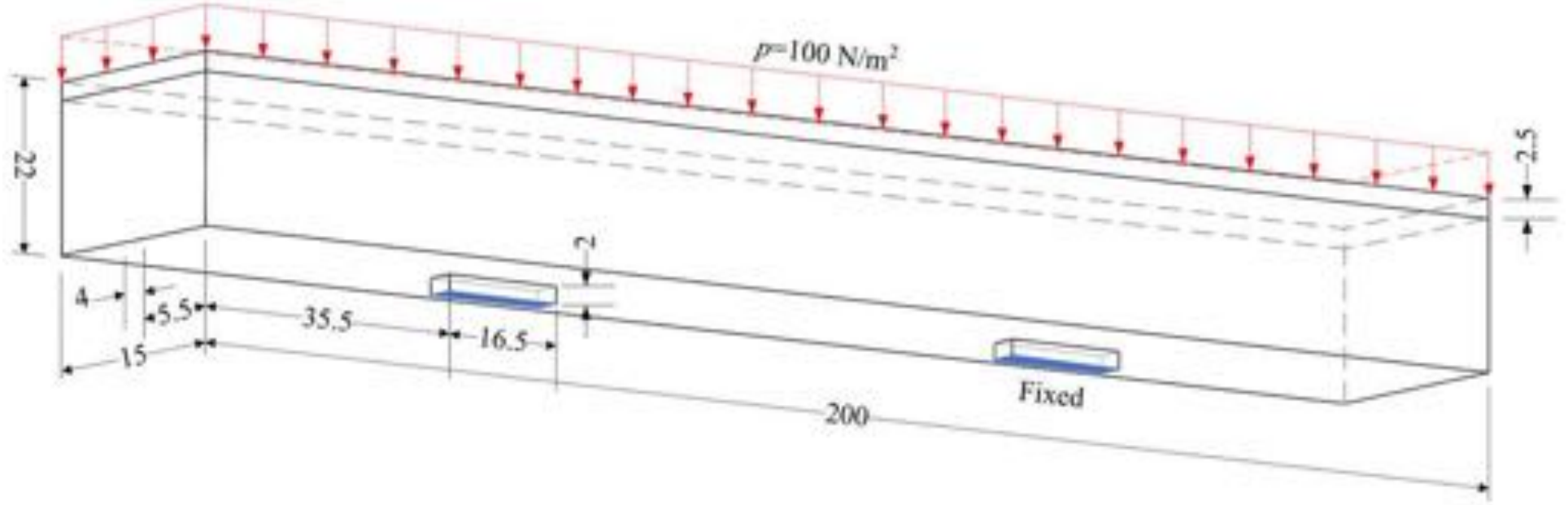
Tactic 2:

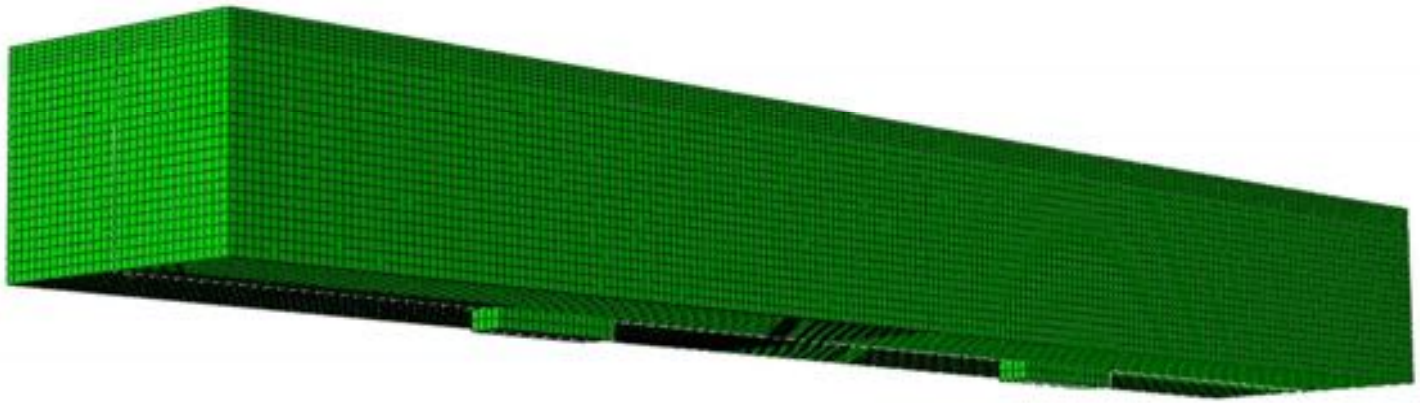
Penalizing existing design(s)

Qatar Convention Centre

(by Arata Isozaki, Mutsuro Sasaki and co-workers)

Extended ESO method was used for form-finding

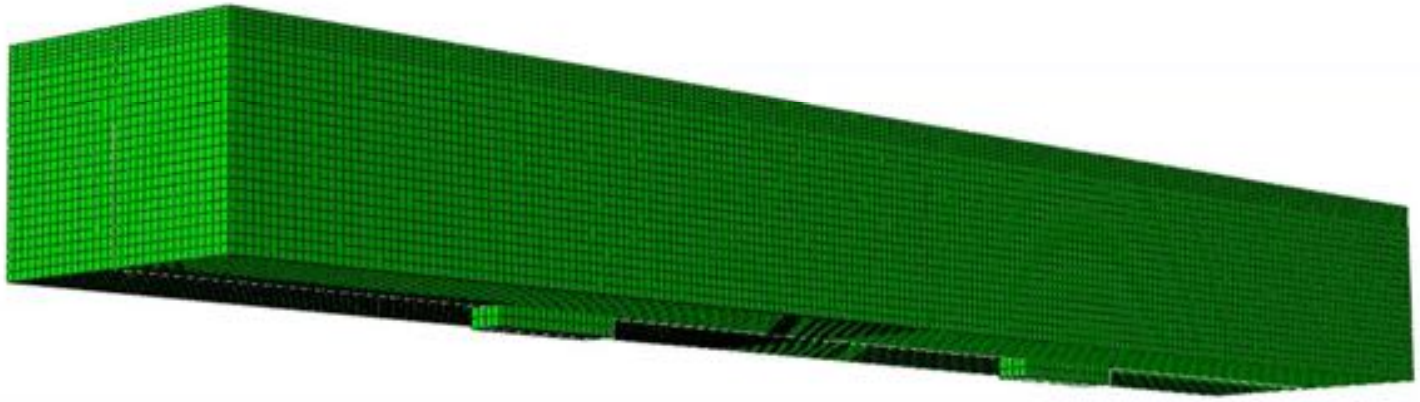

p=100 N/m²
22
2.5
2
4
5.5
35.5
16.5
15
Fixed
200



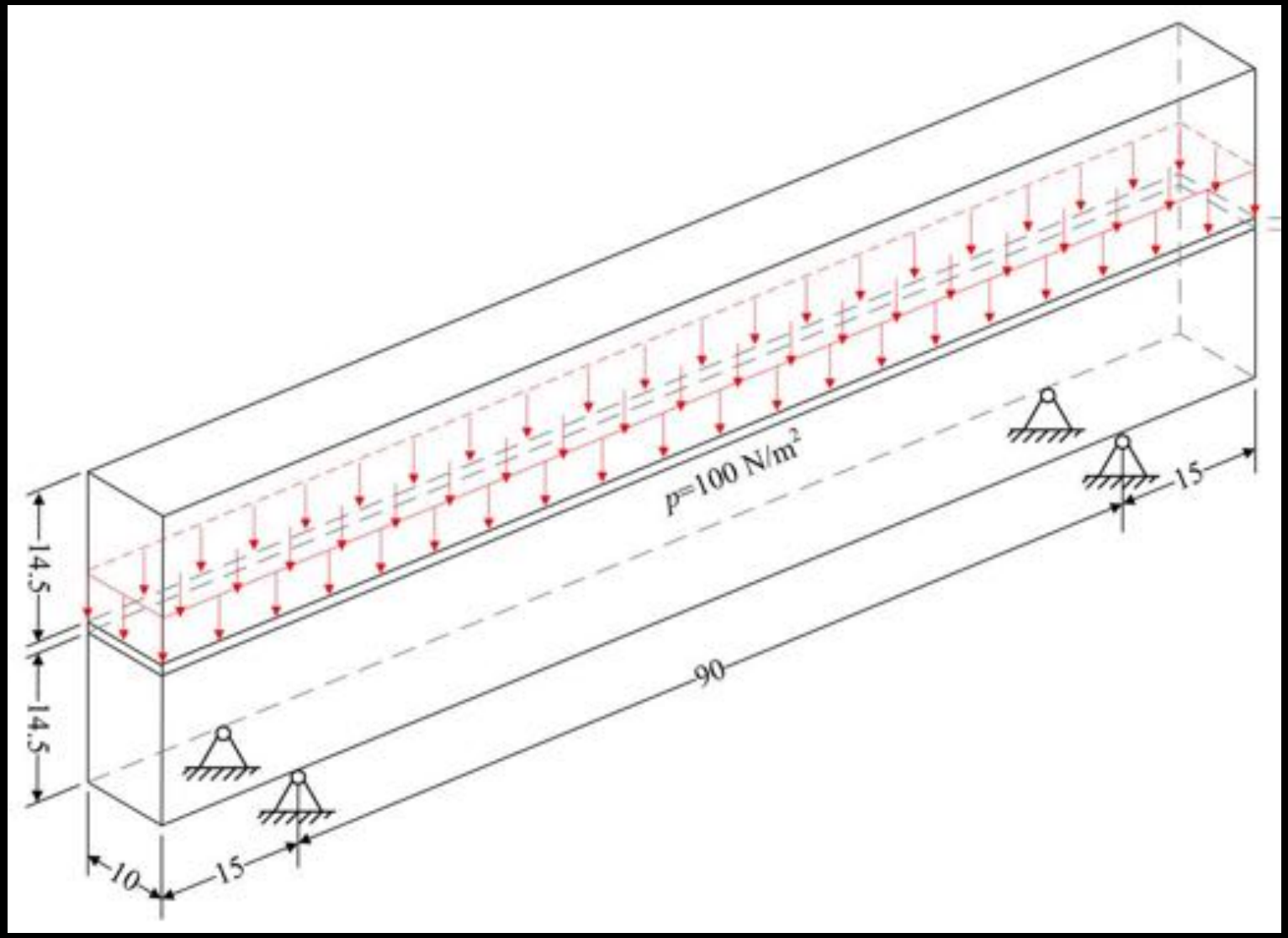
BESO process

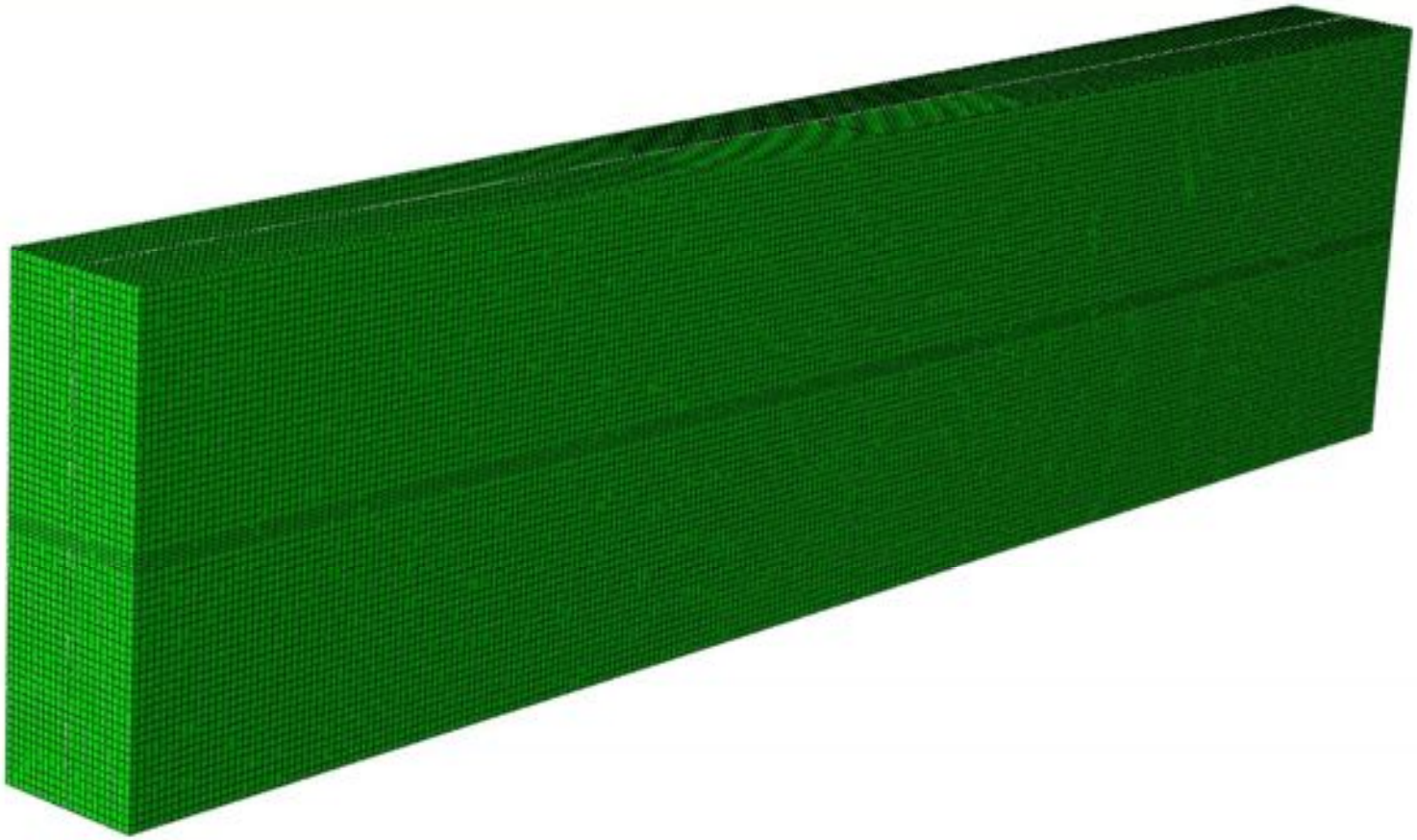

0
25 m

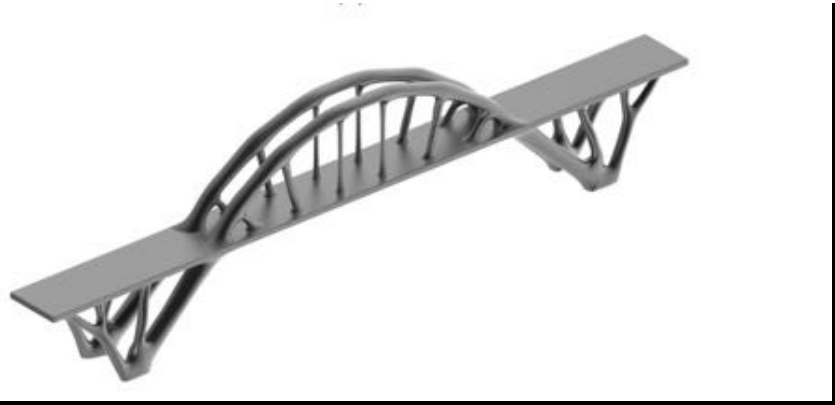

0
25 m

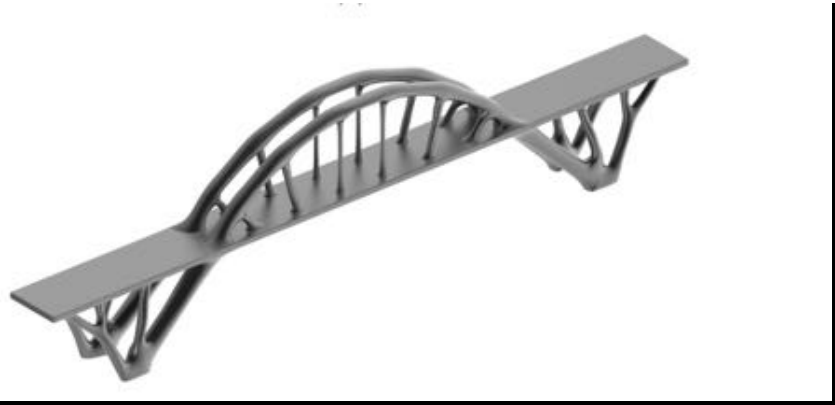


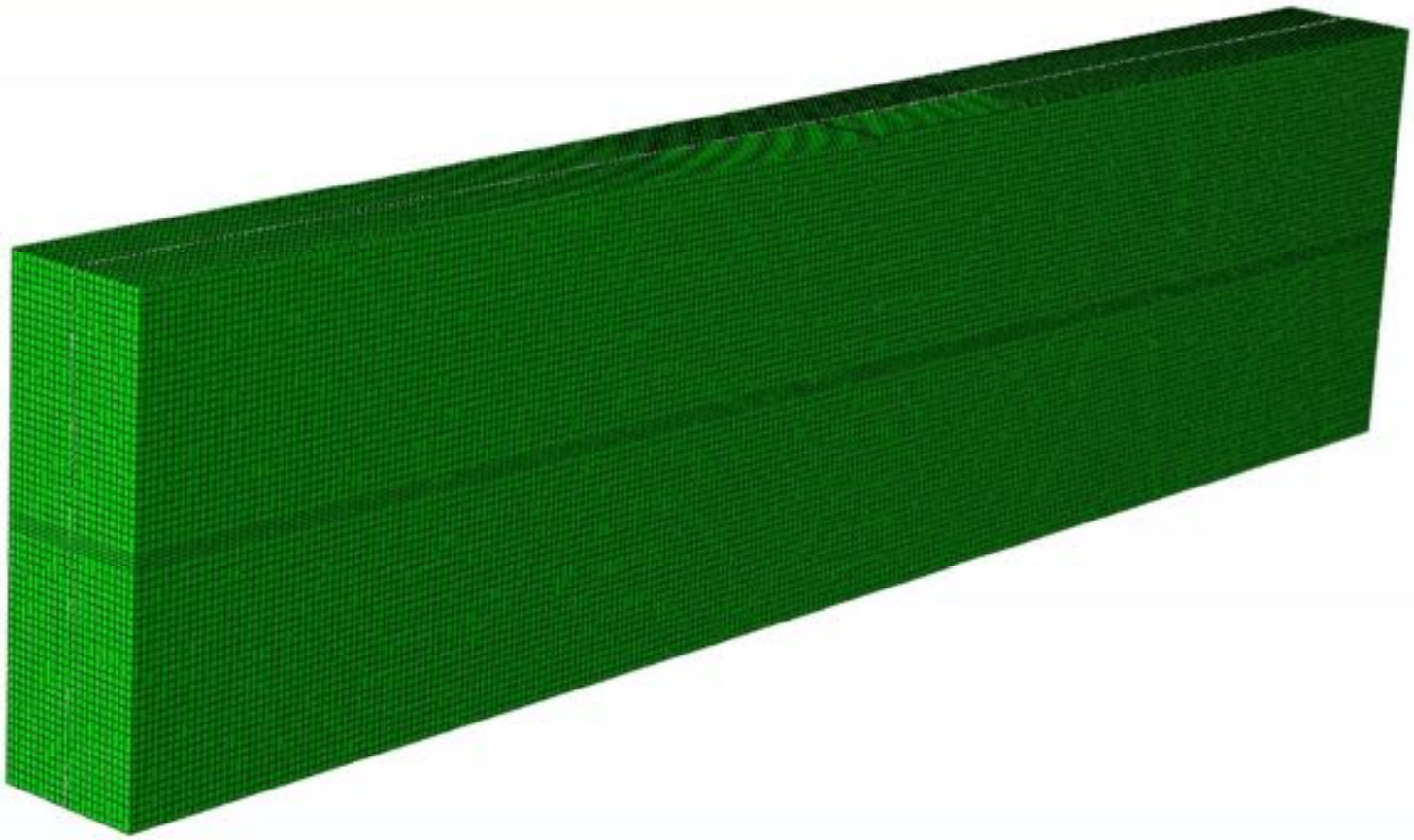
The overall stiffness differs by 9.1%


p=100 N/m²
14.5
14.5
10
15
90
15

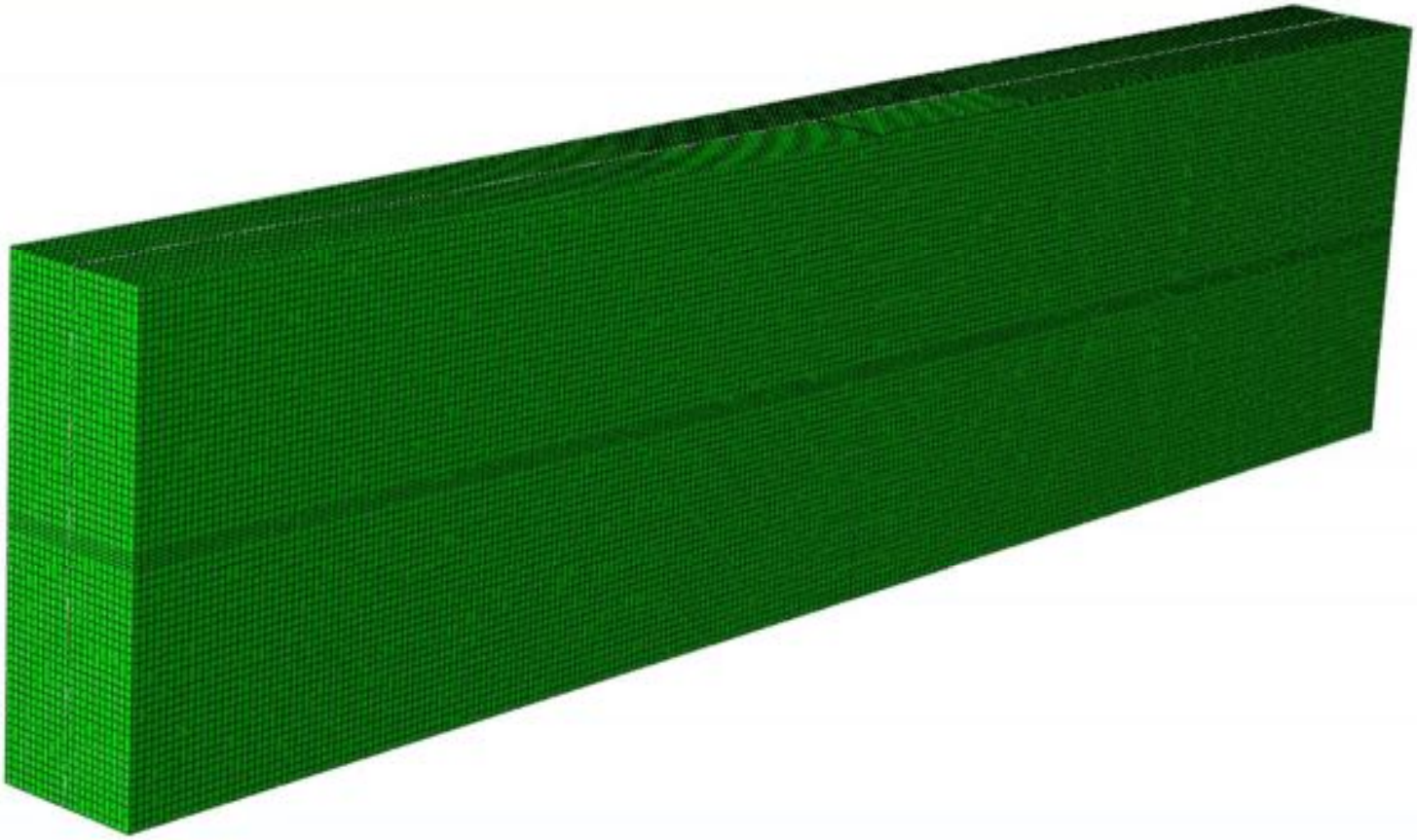








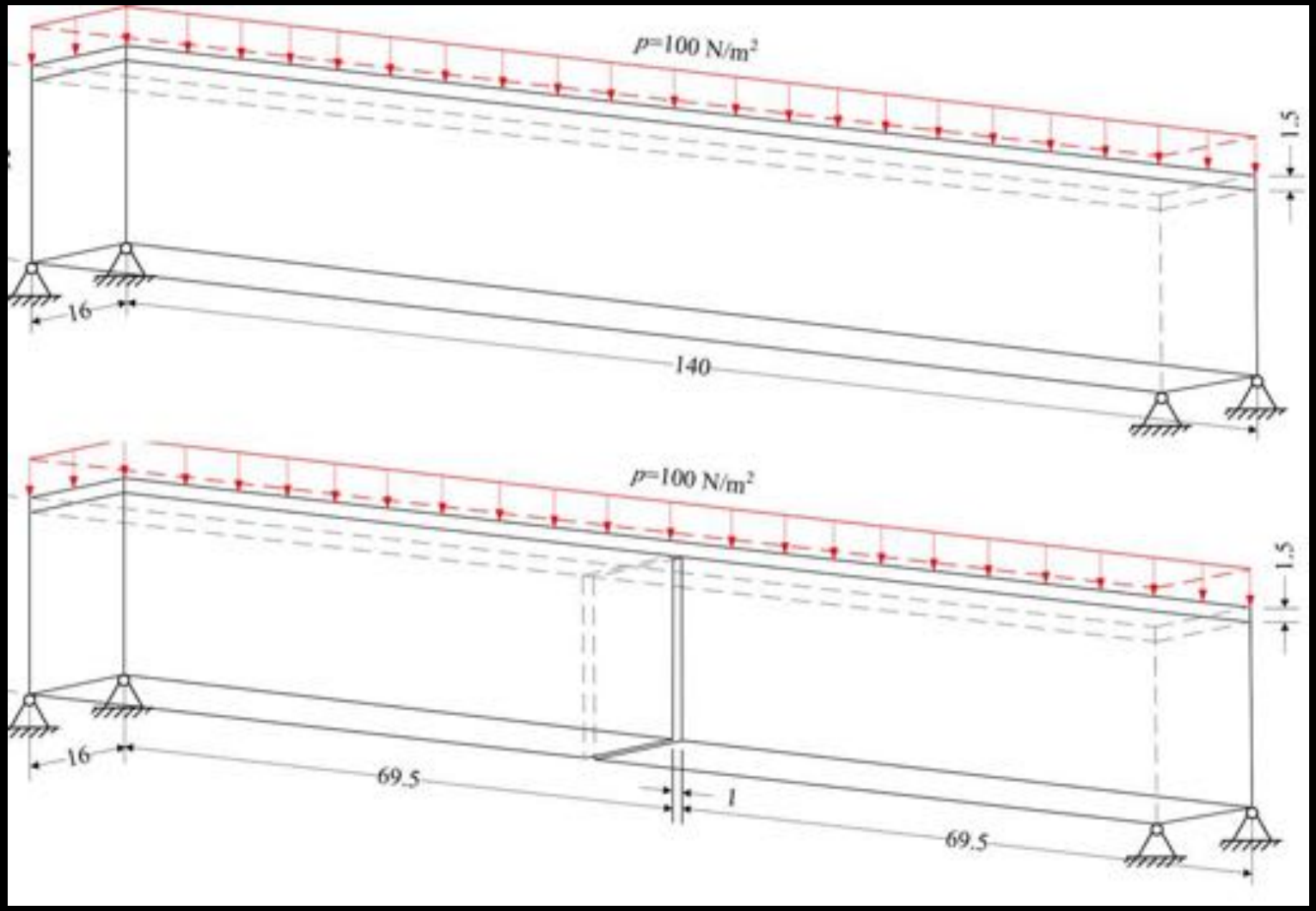
[redacted]

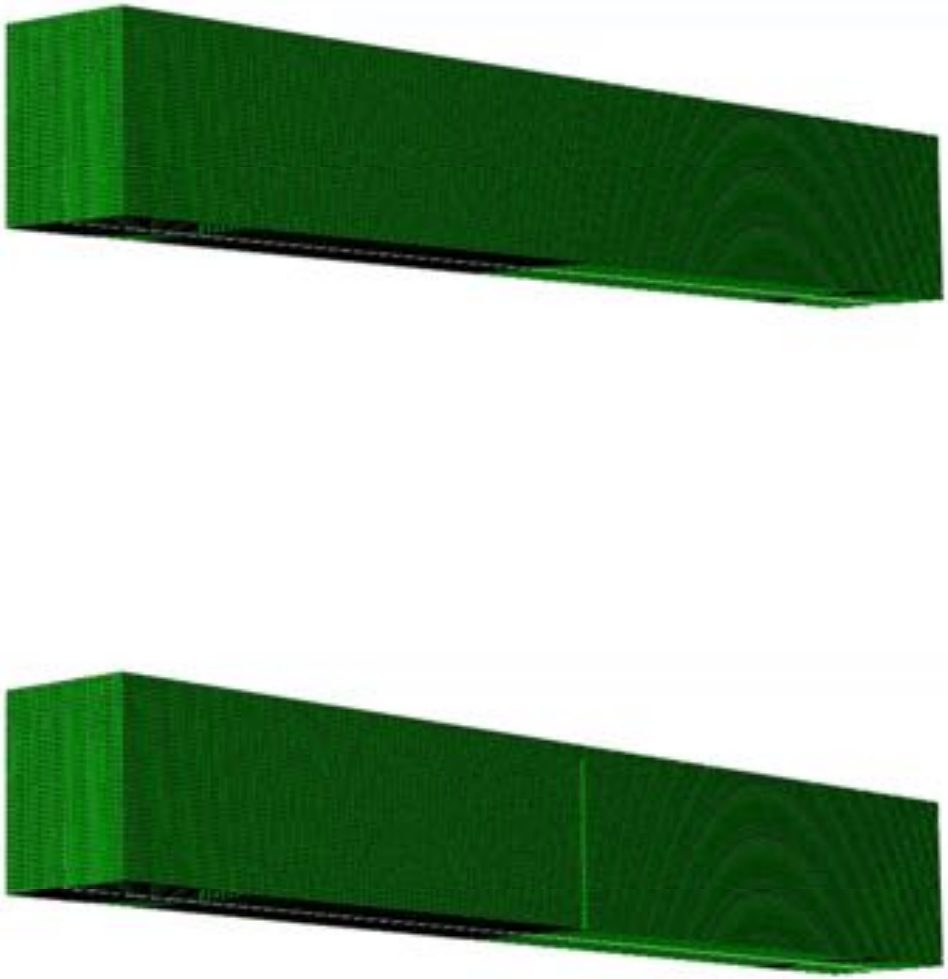


The overall stiffness differs by 3%

Tactic 3:

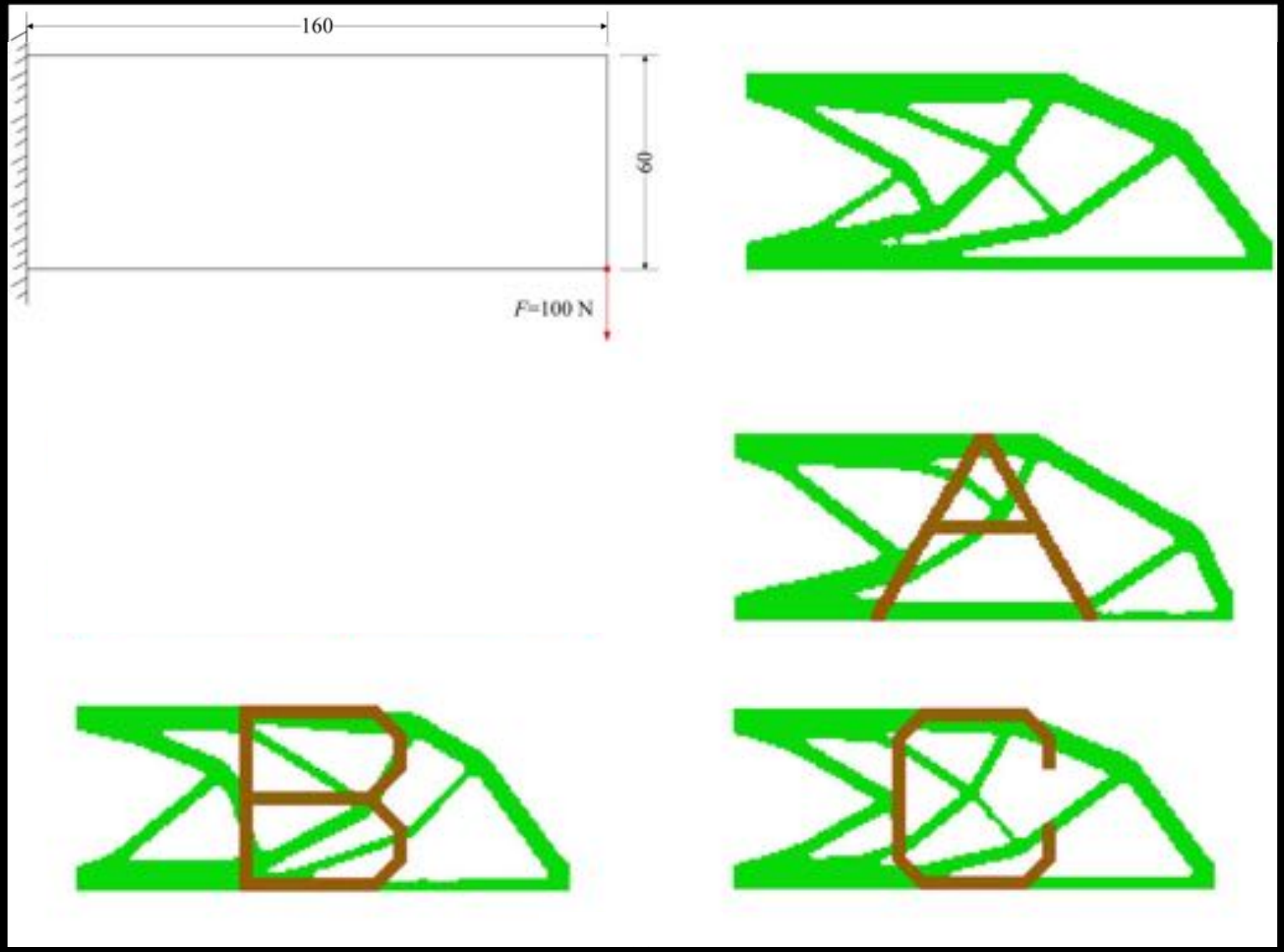
Using constraints as the design *driver*


p=100 N/m²
1.5
16
140
p=100 N/m²
1.5
16
69.5
1
69.5



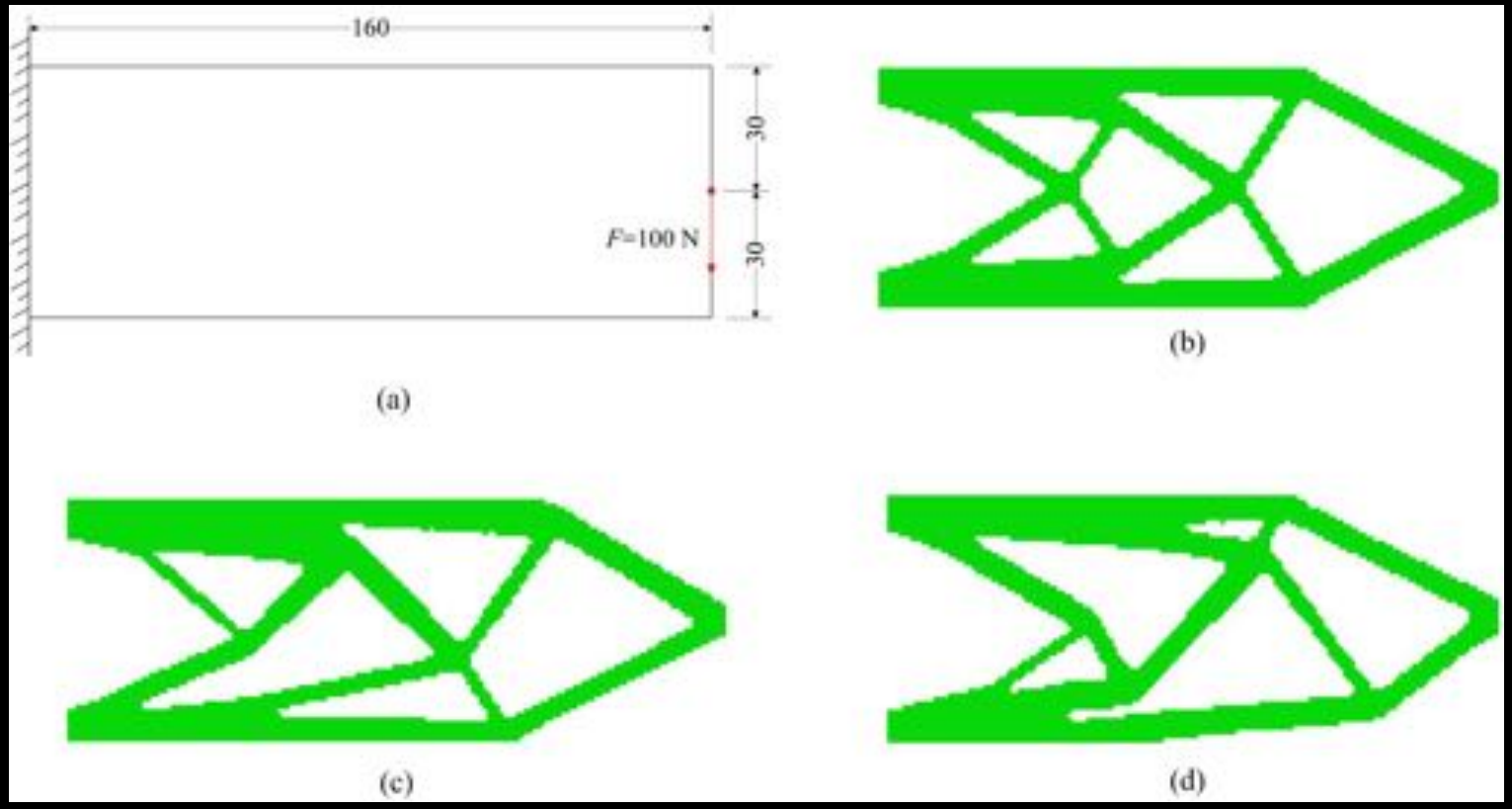
The overall stiffness of the bottom design is 12% lower

Specify Non-design Domain



The overall stiffness differs by 7%

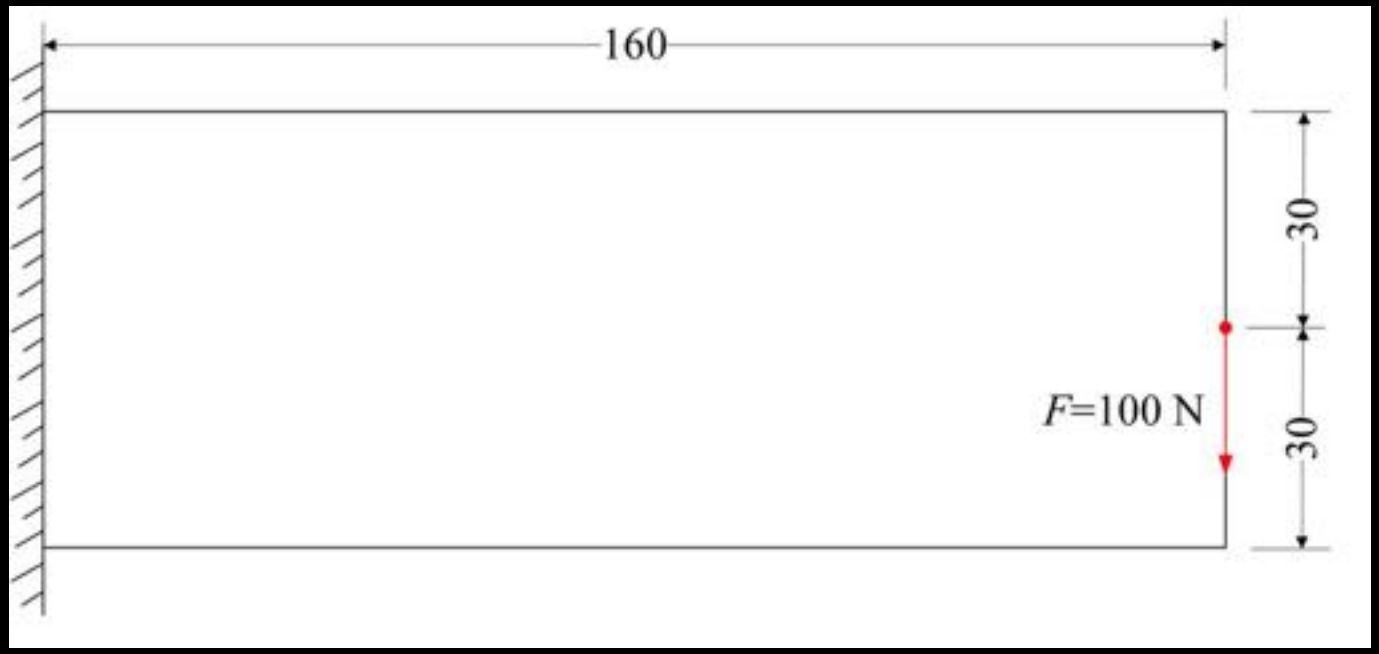
Penalizing Part of the Design Domain

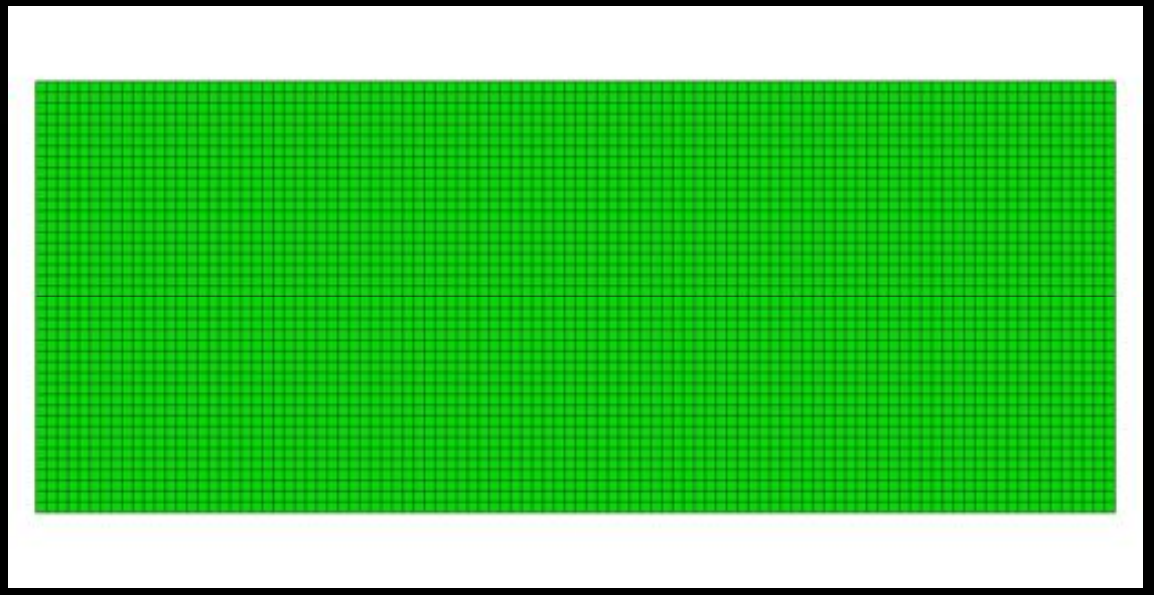


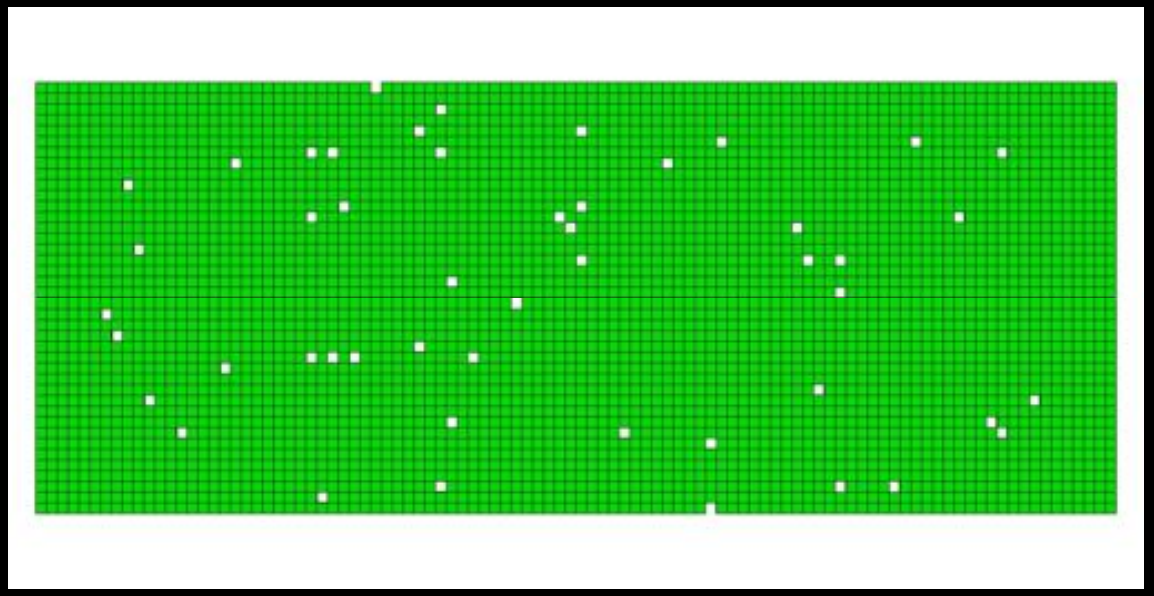
The overall stiffness differs by 4%

Tactic 4:

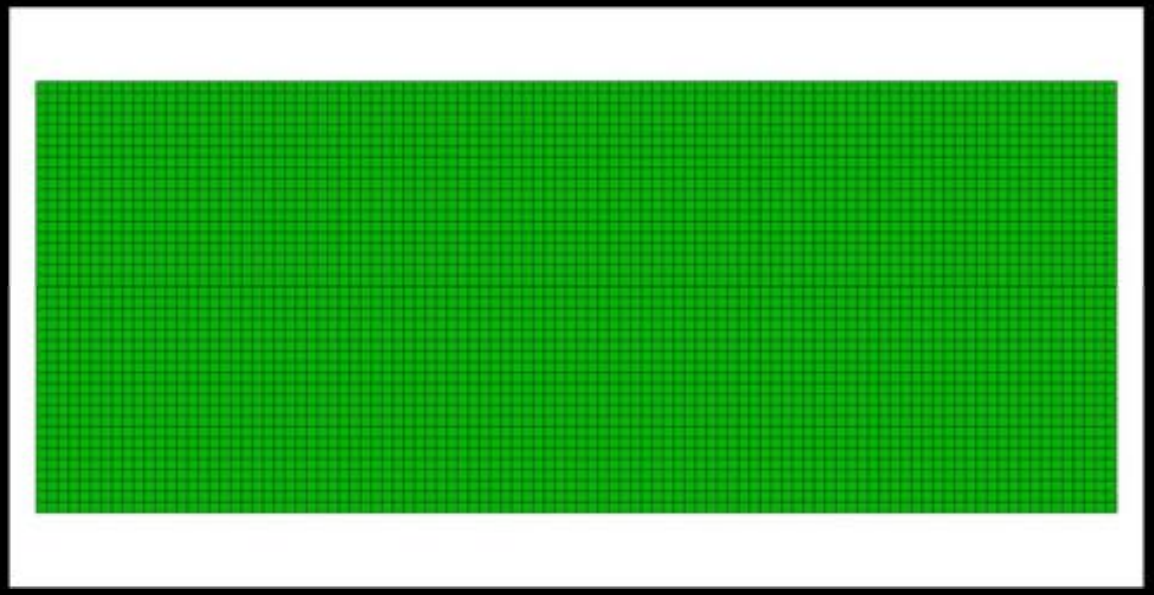
Introducing some random holes in the initial design domain

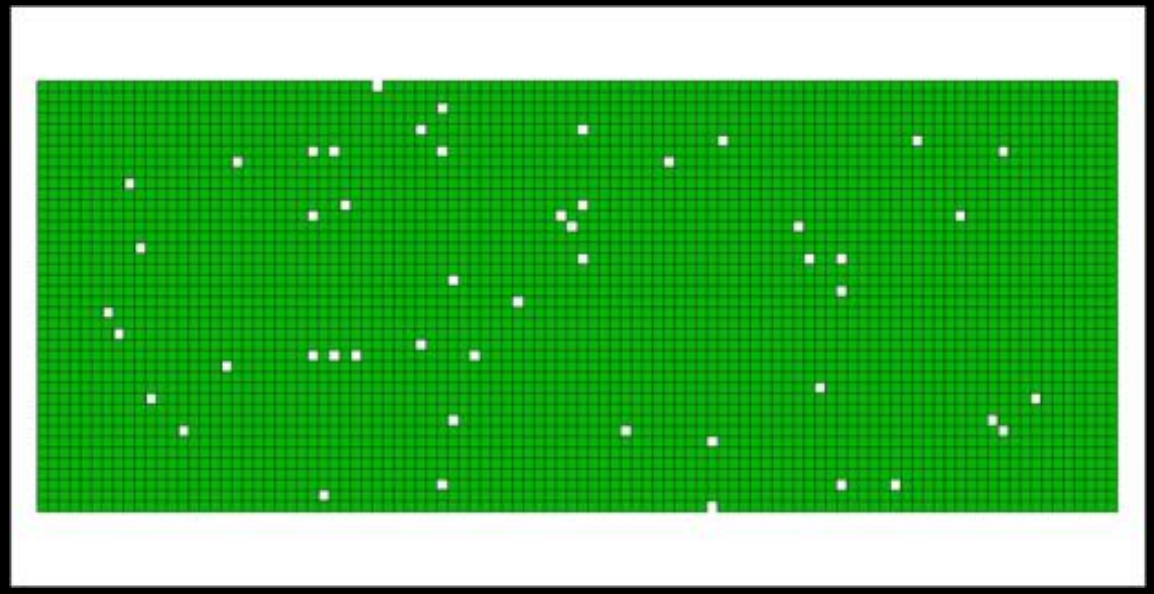

160
30
30
F=100 N





These holes are allowed to be filled, if necessary



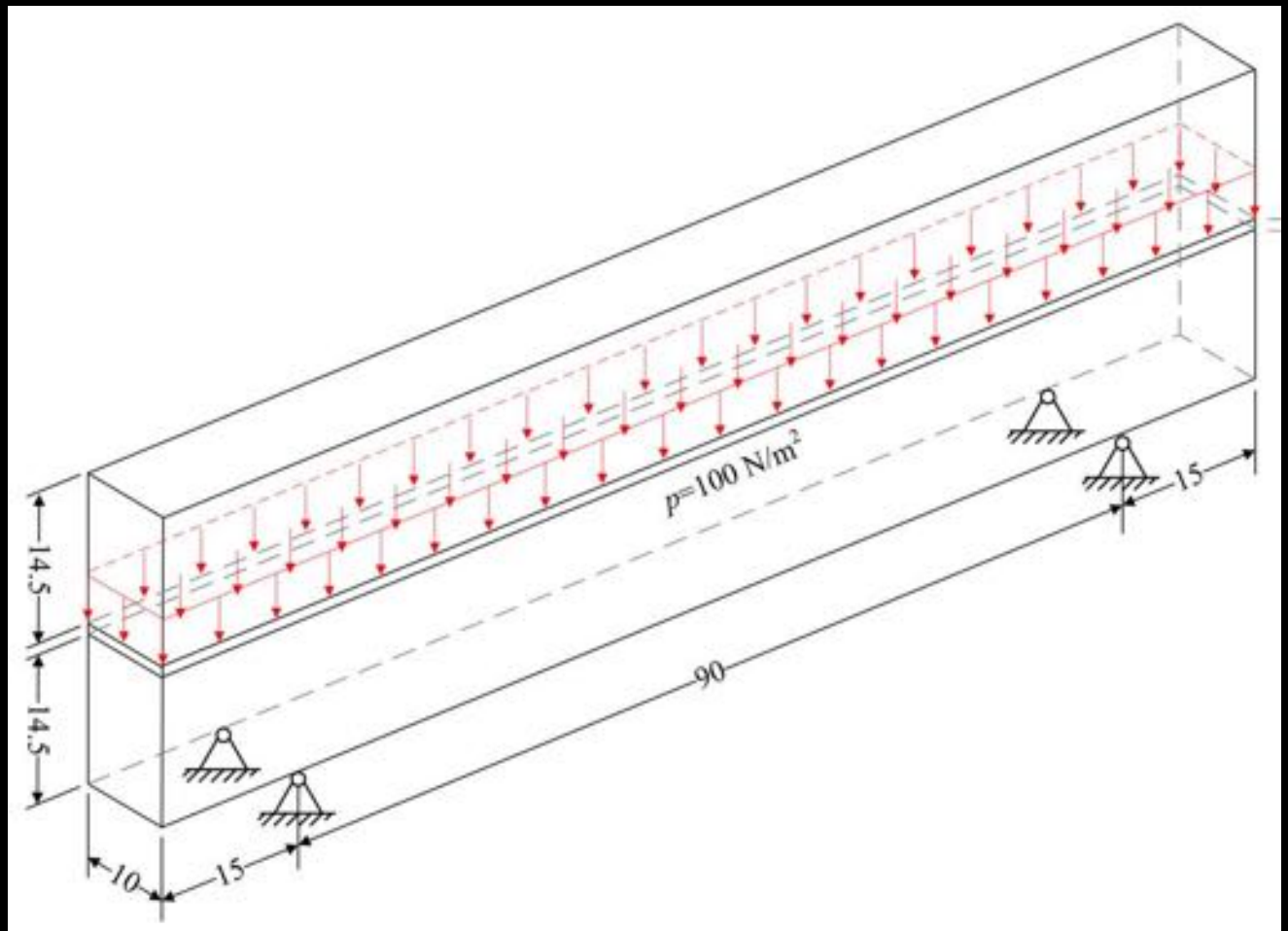


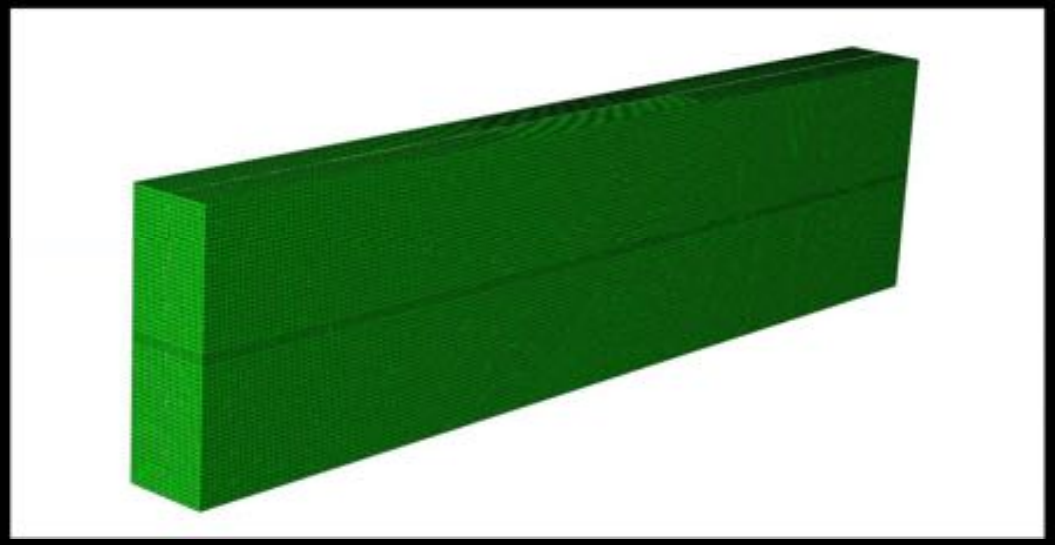
The overall stiffness differs by 2%

Tactic 5:

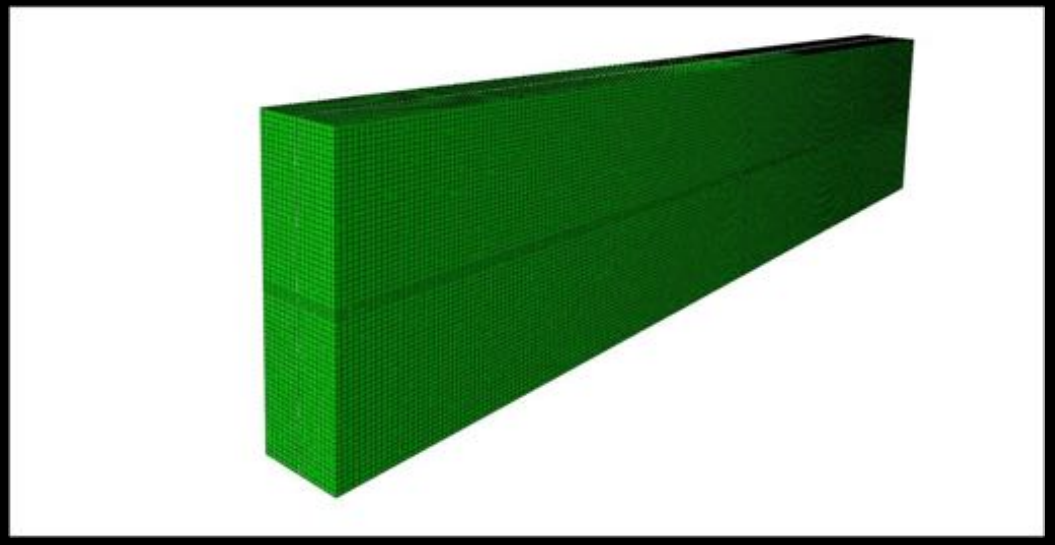
Combining BESO with Genetic Algorithm

Applying crossover and mutation to elements so that their sensitivity rankings are altered


p=100 N/m²
14.5
14.5
10
15
90
15



BESO



BESO
+
Genetic Algorithm

BESO

BESO
+
Genetic Algorithm

The overall stiffness differs by 1.5%

Conclusions

- We have proposed and demonstrated several simple and effective tactics for achieving topologically different and structurally efficient designs
- Such diverse and competitive designs are of practical importance to architects and other designers
- The same tactics can be applied to other topology optimization methods

References and Contact

K. Yang, Z.L. Zhao, Y. He, S. Zhou, Q. Zhou, W. Huang, Y.M. Xie. Simple and effective strategies for achieving diverse and competitive structural designs, *Extreme Mechanics Letters* 30 (2019) 100481.

Y. He, K. Cai, Z.L. Zhao, Y.M. Xie. Stochastic approaches to generating diverse and competitive structural designs in topology optimization, *Finite Elements in Analysis and Design* 173 (2020) 103399.

E-mail address: **mike.xie@rmit.edu.au**

Background: BESO bridge design by Yi Min 'Mike' Xie and Dingwen 'Nic' Bao