Aerodynamic water droplet with strong lightweight bone structure

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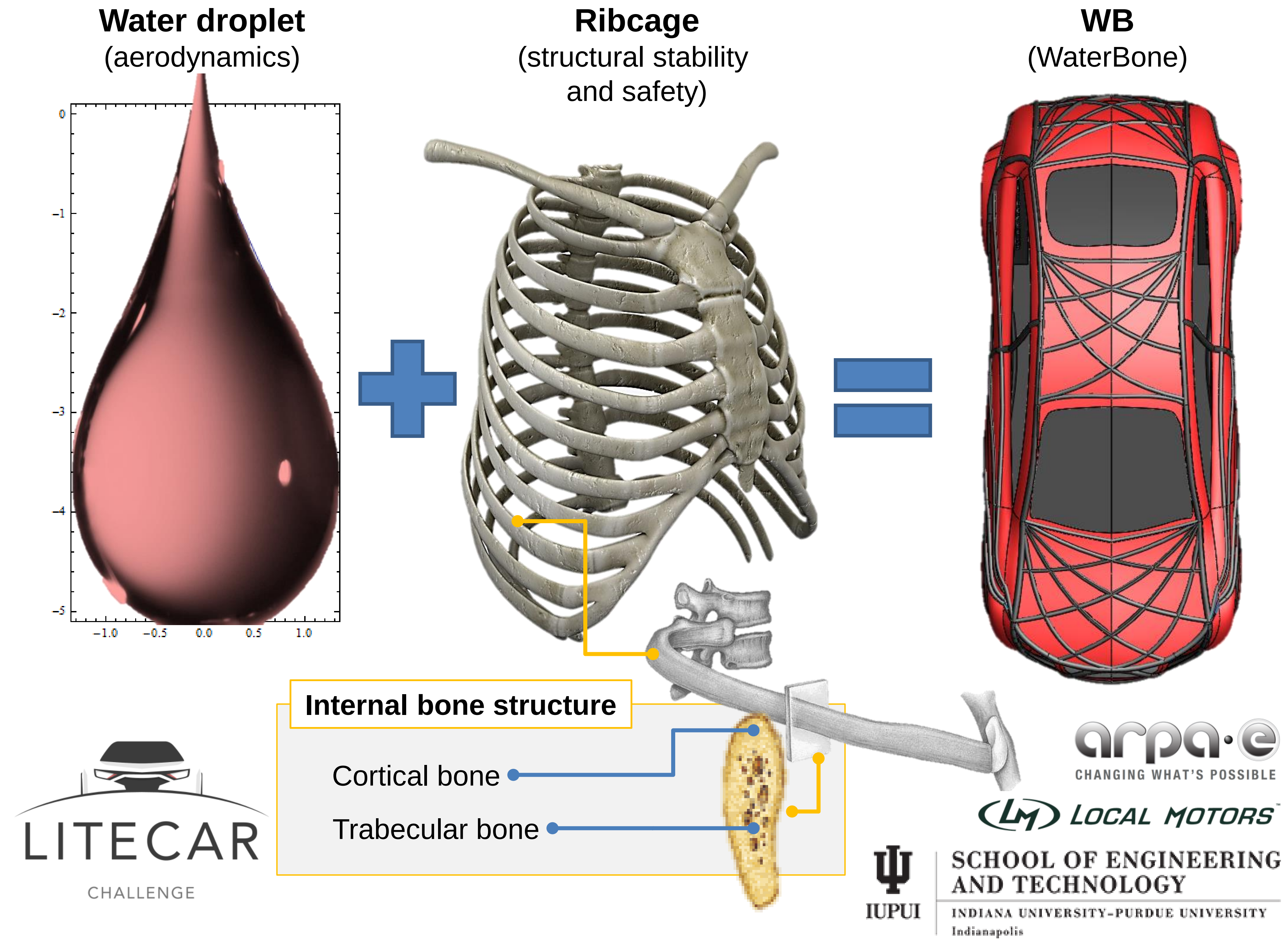
Water droplet
(aerodynamics)
0
−1
−2
−3
−4
−5
−1.0
−0.5
0.0
0.5
1.0
Ribcage
(structural stability
and safety)
WB
(WaterBone)
Internal bone structure
Cortical bone
Trabecular bone
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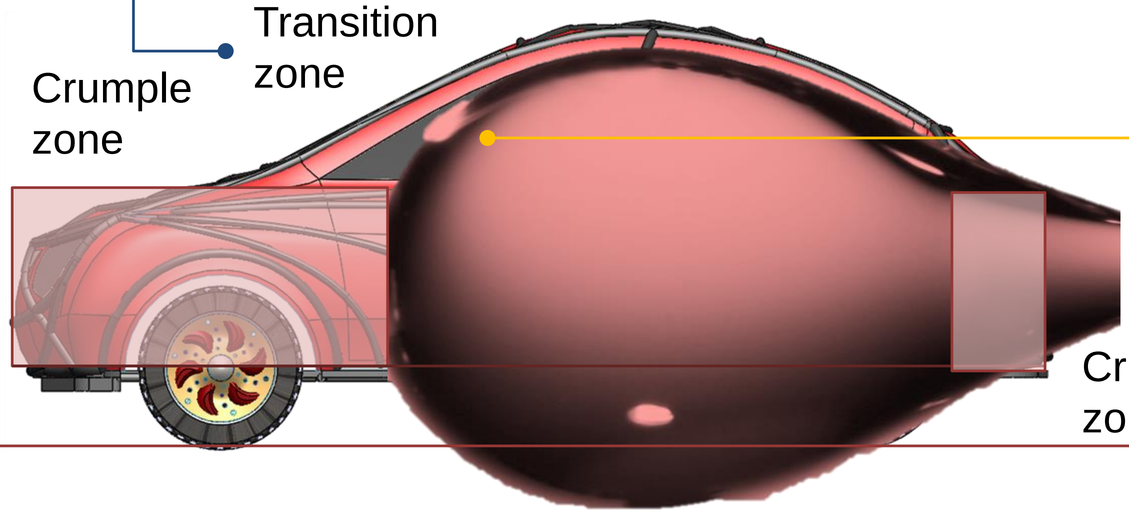
Aerodynamic design + crumple zone for occupant safety

The waterdrop design provides low drag coefficient. The addition of a crumple zone decreases this coefficient but allows to dramatically increasing crashworthiness indicators.

The drag coefficient of a waterdrop is 0.04. The expected drag coefficient of the BW car is 0.25, which is still lower than most sedans in the market.



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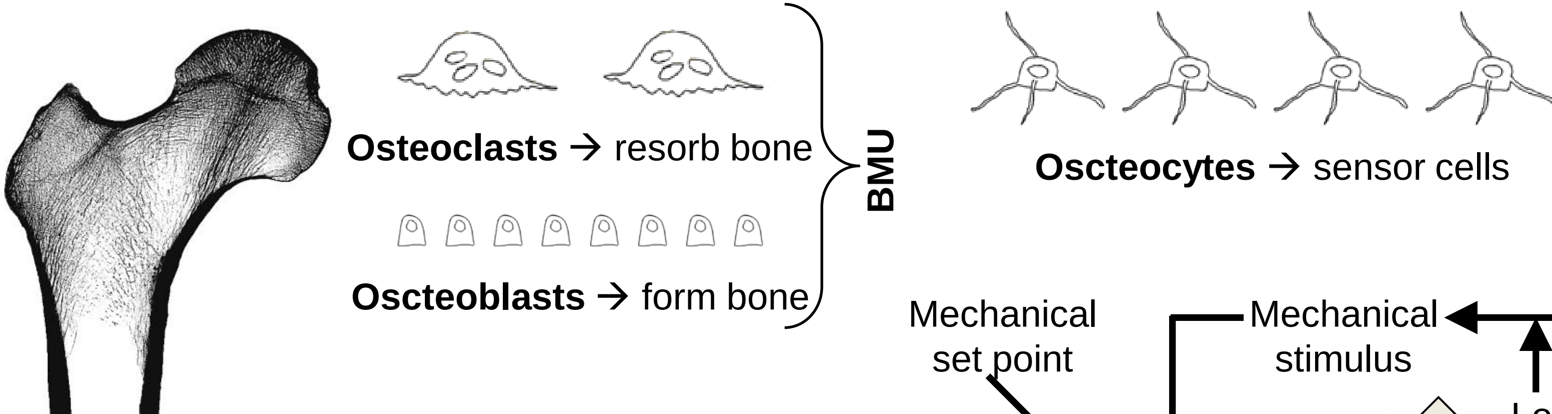
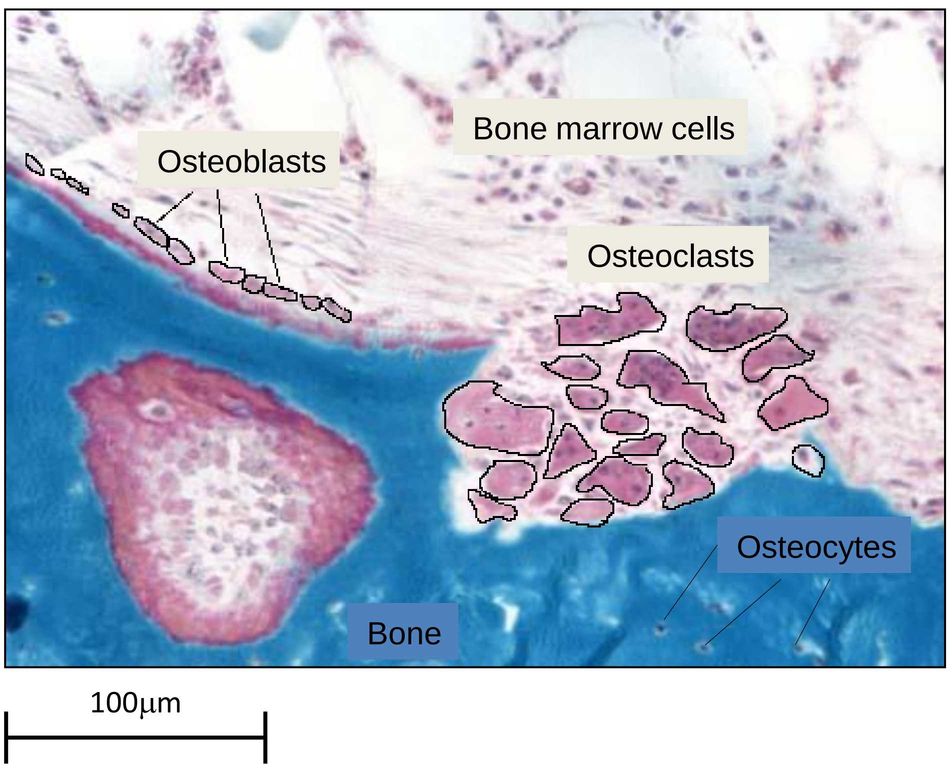
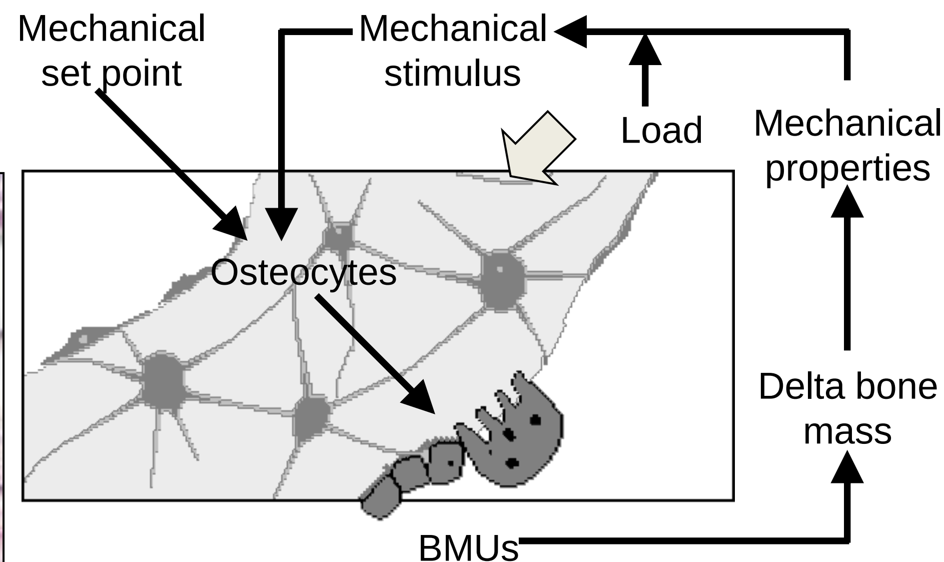
Learning from bone to optimally distribute material (topology optimization)







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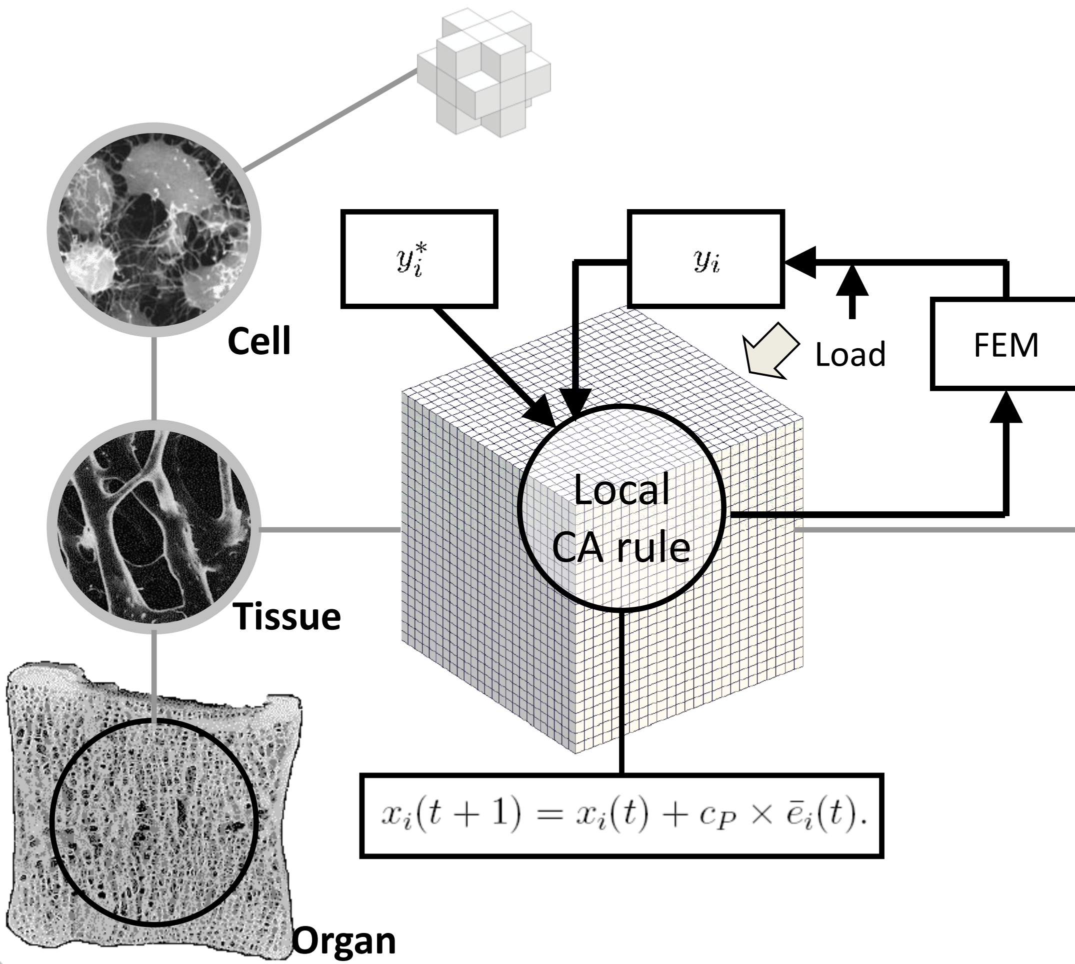
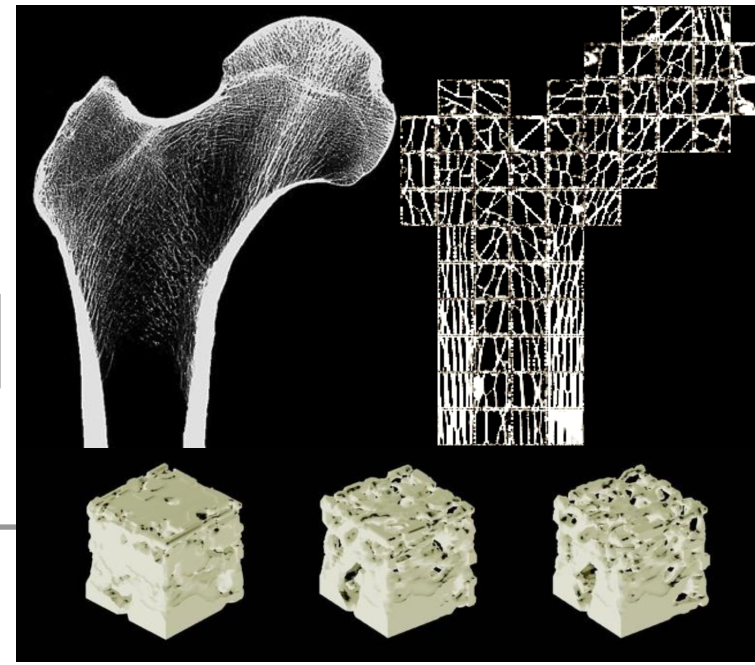
Topology optimization achieved with a Hybrid Cellular Automaton (HCA) algorithm



Trabecular (graded porous) structure



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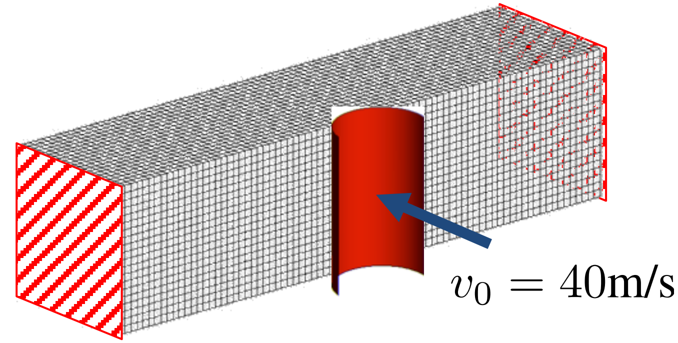
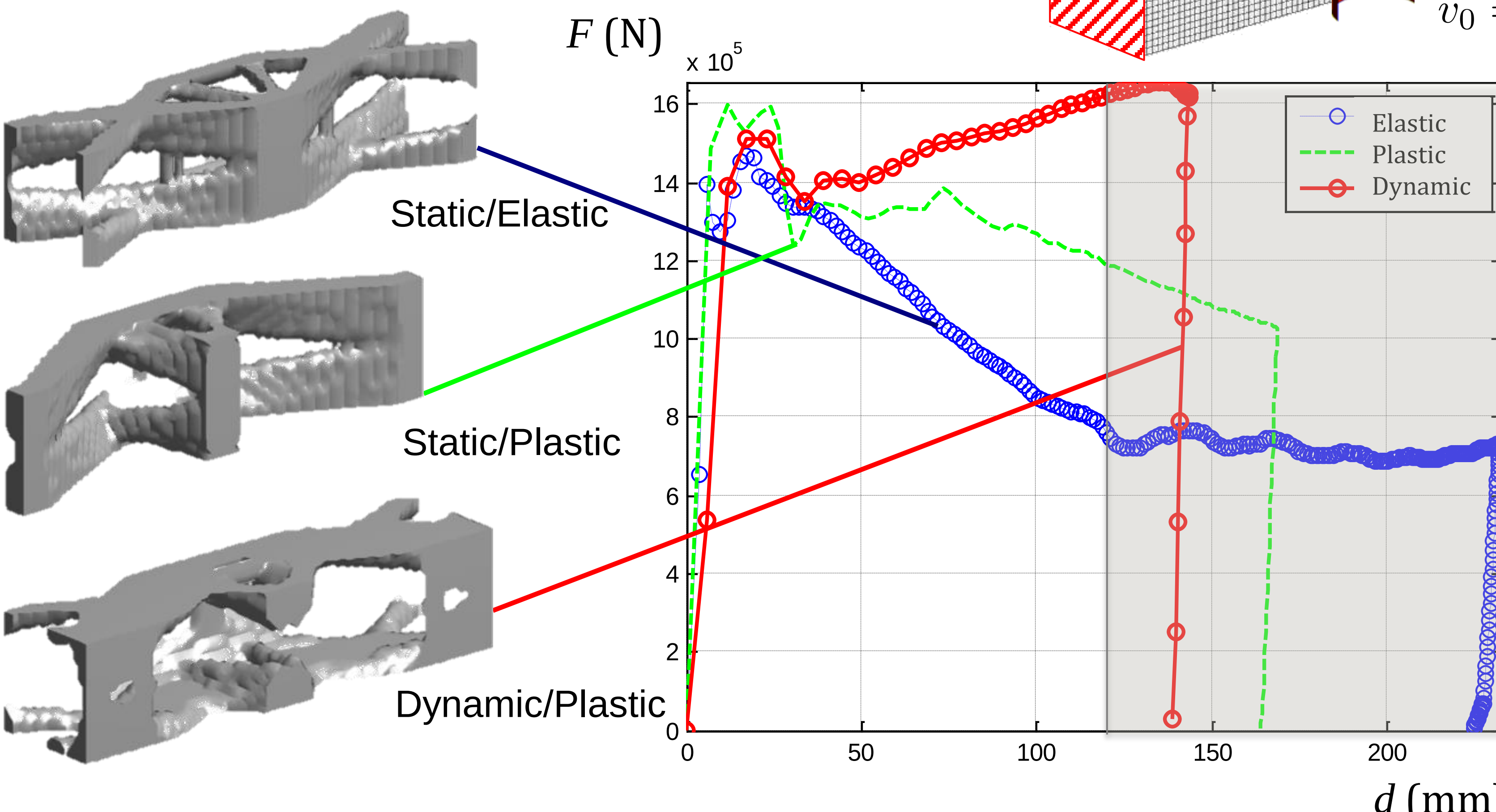
Topology optimization of a bumper: solid design

$$\min_{0 \le \rho_i \le 1} \quad -U(\boldsymbol{\rho}, d = \hat{d}), \quad \hat{d} = 120\text{mm}$$

$$\text{subject to} \quad M(\boldsymbol{\rho}) - 0.2 M_0 = 0$$

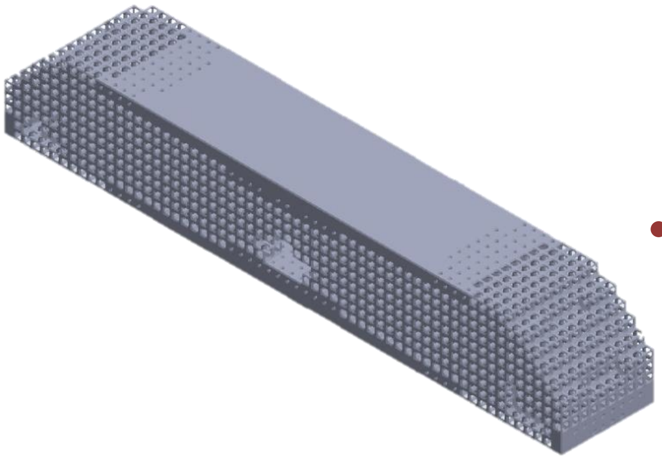


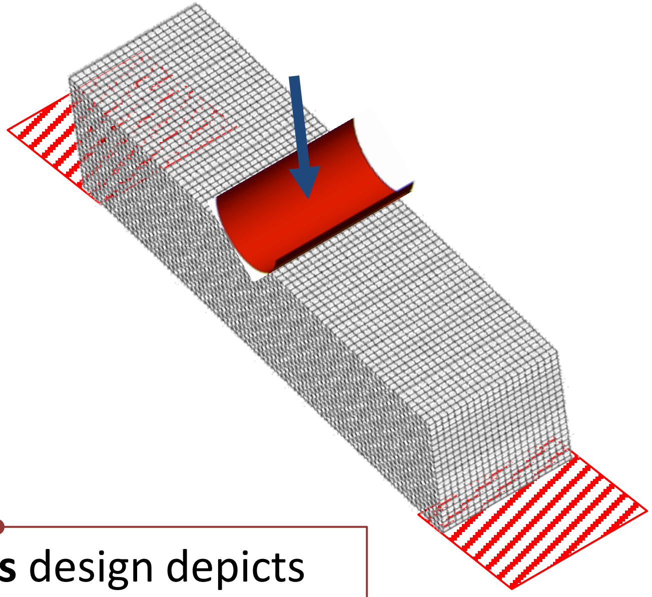


Patel, Tovar et al., Journal of Mechanical Design, 2009

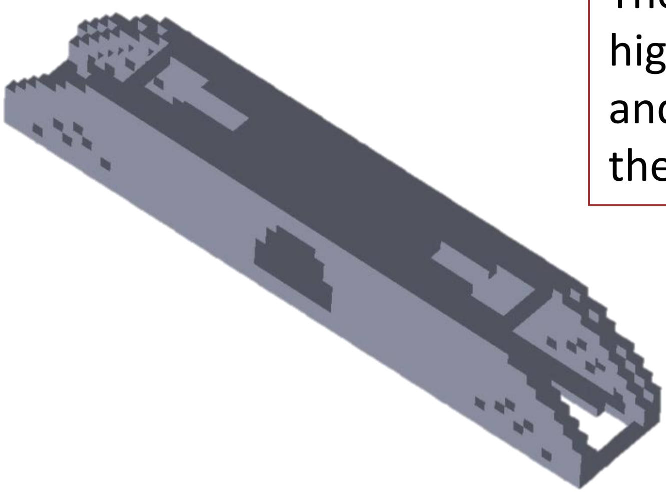
Topology optimization of a bumper: trabecular (graded porous) vs. solid design

Trabecular (graded porous) structure





Solid structure



The **graded porous** design depicts higher specific energy absorption and lower peak crushing force than the solid structure

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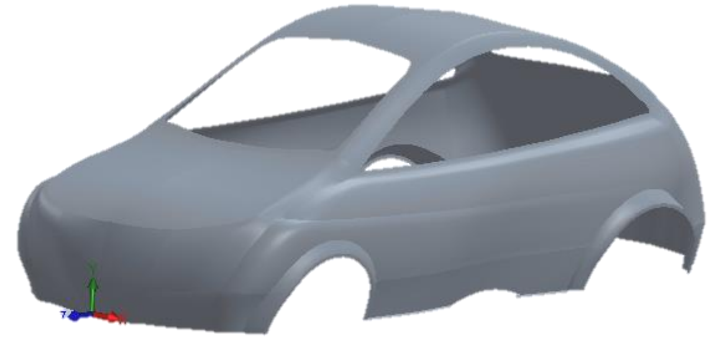
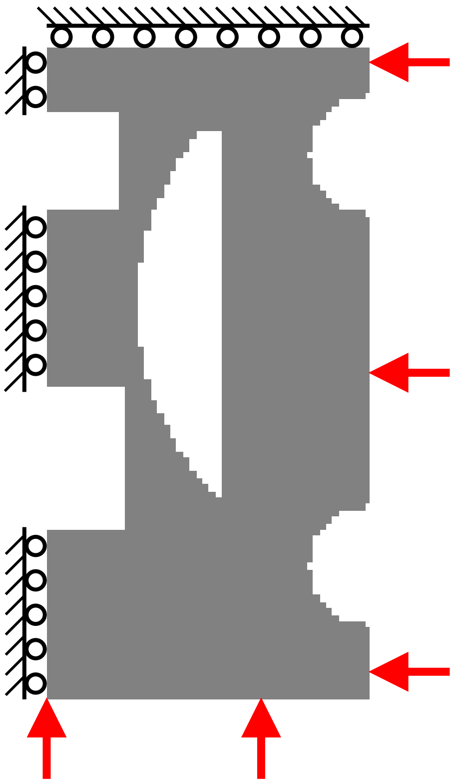
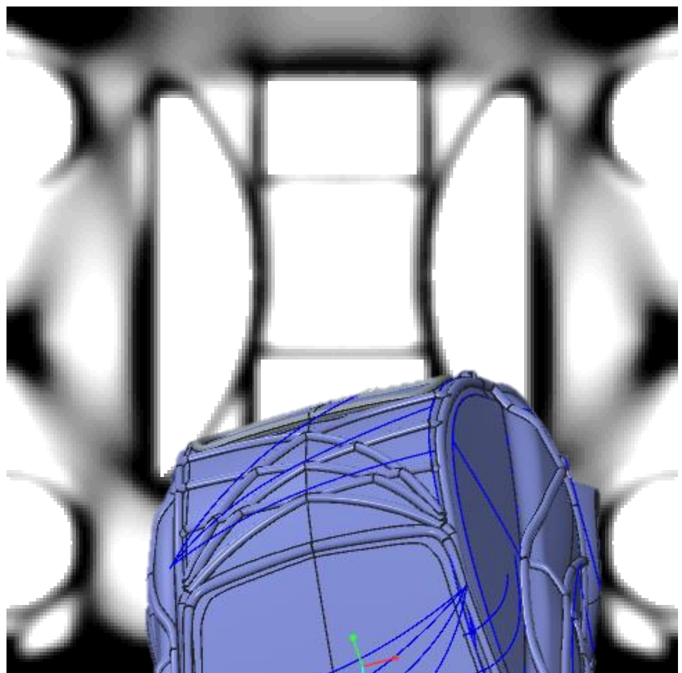
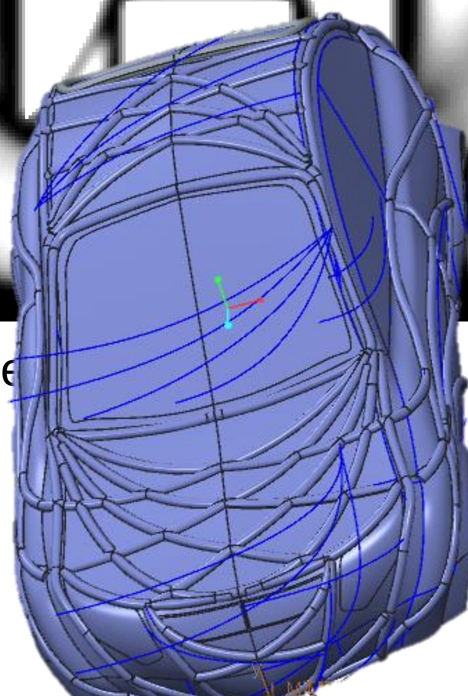
Initial material distribution for the preliminary spaceframe design



Design domain with five loading cases







Grade

Solid design

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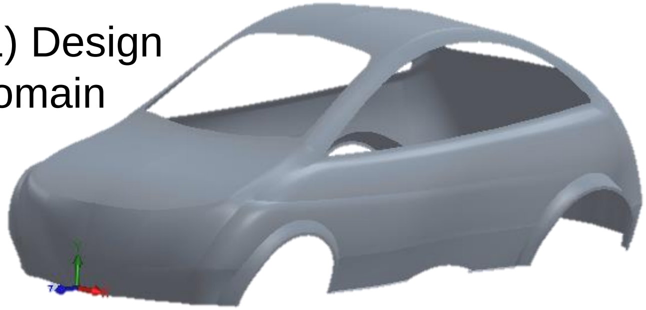
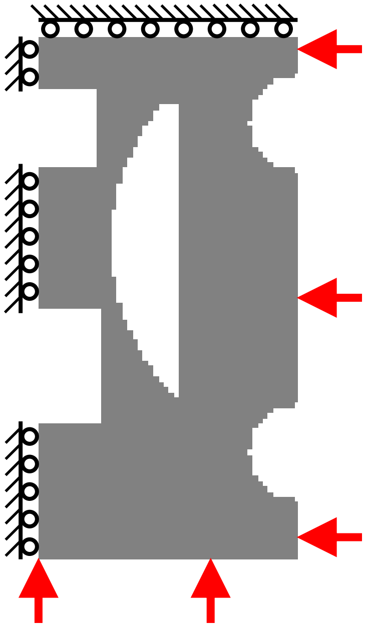
Initial material distribution for the preliminary spaceframe design

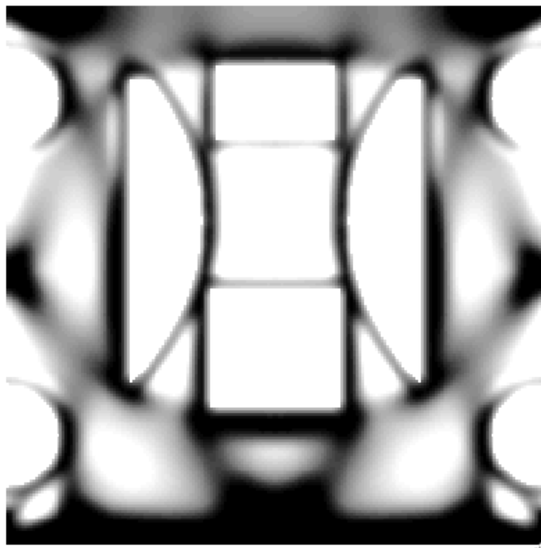
(1) Design domain



(2) Five loading cases

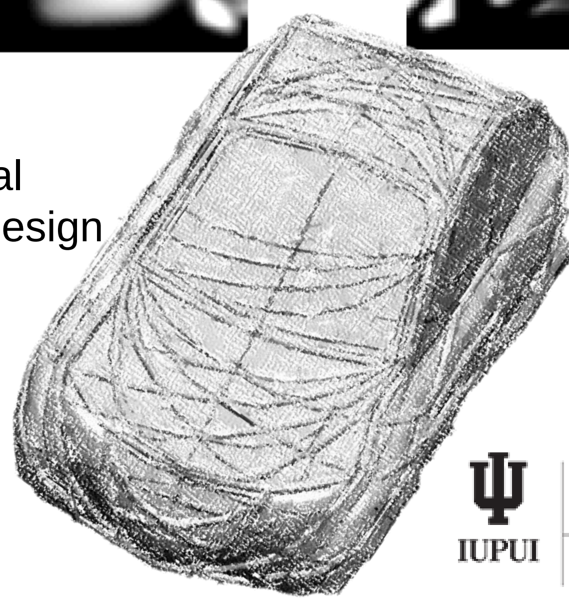


(3) Graded porous design



(4) Solid design

(5) Conceptual spaceframe design



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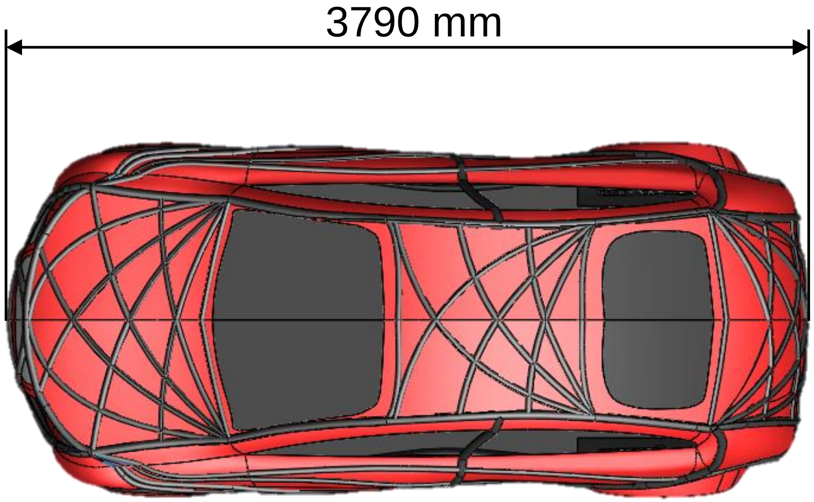
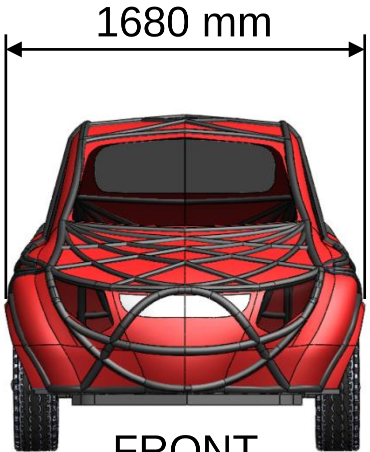
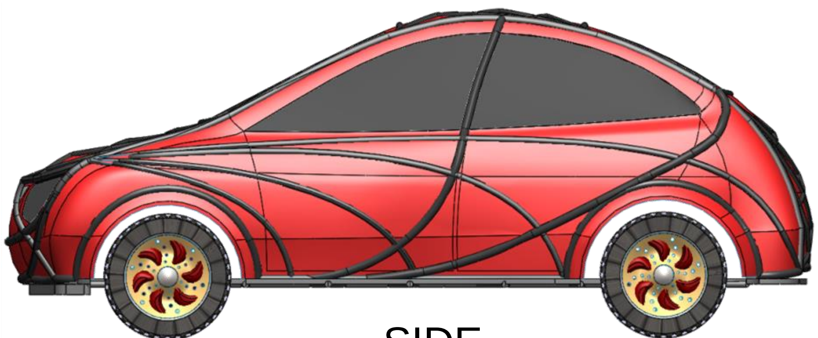
Final concept design



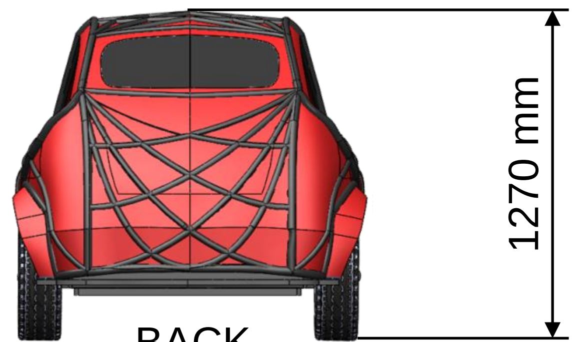
TOP



FRONT

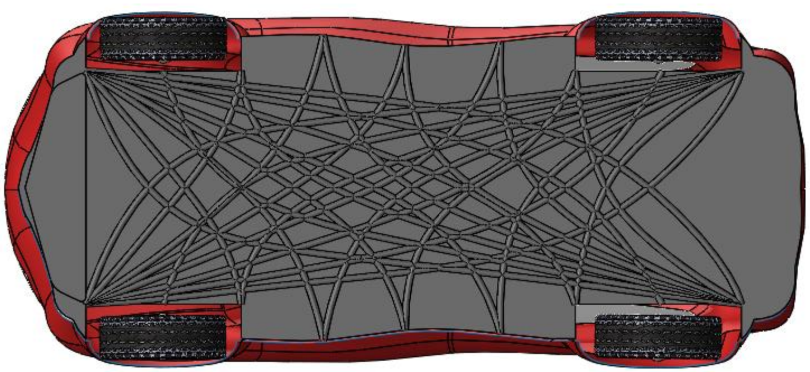


SIDE



BACK

Weight = 134 kg
(295 lb),
63% Aluminum
37% ABS
(in weight)



BOTTOM

Each element of the ribcage (spaceframe) has a graded porous structure, similar to a bone

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