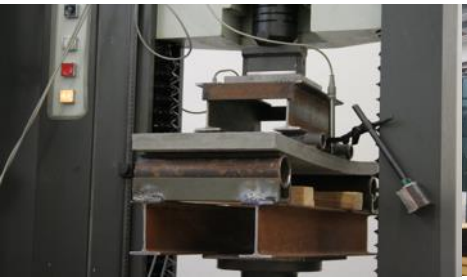
Petr Hájek
Czech Technical University in Prague
Faculty of Civil Engineering, Department of Building Structures

Progressive precast and demountable construction system
from HPC for sustainable and resilient buildings




The adaptation of humans to changing conditions should be supported by higher performance quality and resilience of the whole built environment

Structures and all built environment should be better prepared for new conditions – they should be ***sustainable*** and ***resilient***

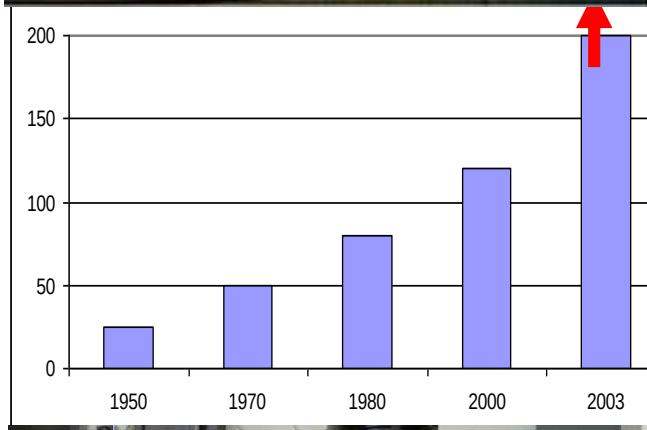
Role of concrete and concrete structures

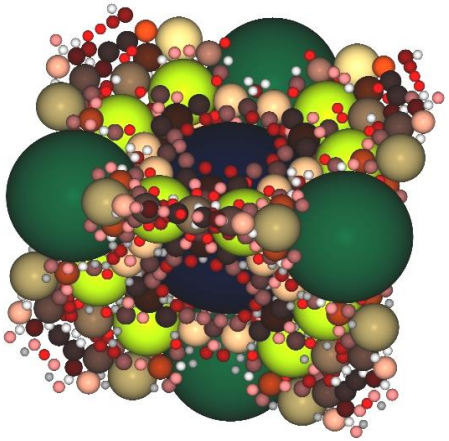
- **New situations require new technical solutions** for construction of new and reconstruction of existing structures.
- Concrete is material with **high potential for new technical solutions** resulting in **environmental impact reduction**
- **High structural safety, reliability, and higher fire resistance of concrete** results in a **high resistance to extreme conditions** during natural disasters
- With respect to specifics of concrete it is possible to design **robust structures with high level of resilience** when faced to the natural or man-made disasters.

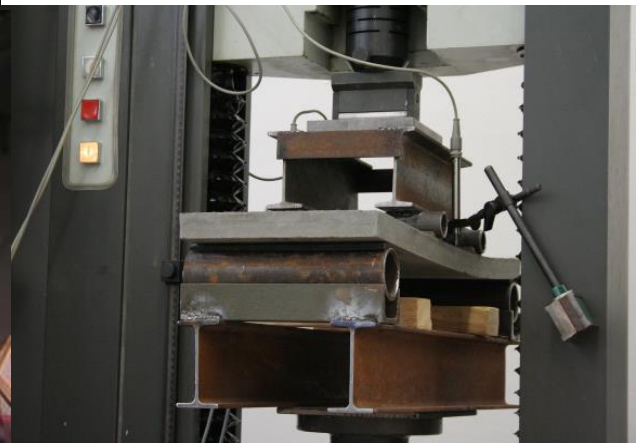
advanced technological and structural principles

Optimisation of concrete mixture

- use of cement with reduced environmental impacts
- use of recycled concrete in new concrete mix
- concrete constituents from waste materials (fly ash, microsilica, etc.)
- new types of composite materials with programmed mechanical properties (SCC, FRC, HPC, UHPC etc.)





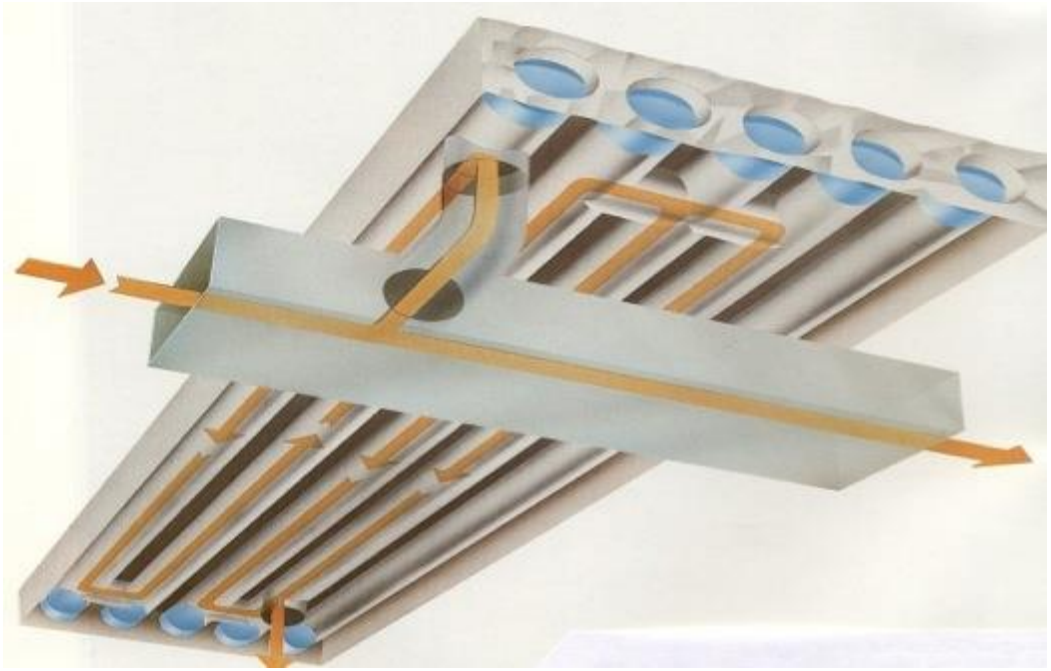


Shape optimisation

- more effective structural shape
- **material savings 30 – 60%**
- lighter structures
  savings on supporting structures
- lower costs / environmental impacts
  from construction, transport and
  demolition

Thermal mass of concrete

- thermal activated concrete core
- reduction of energy consumption - especially for cooling
- improvement of internal environment



Advanced concrete technologies

TRC – textile reinforced concrete

2D and 3D textile reinforcement

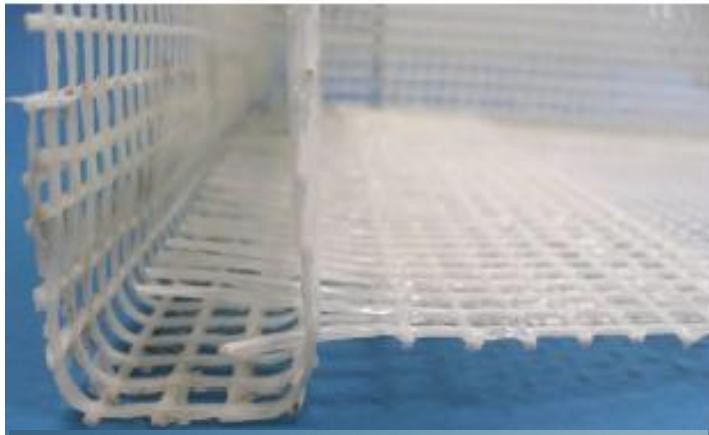
Self cleaning concrete surface

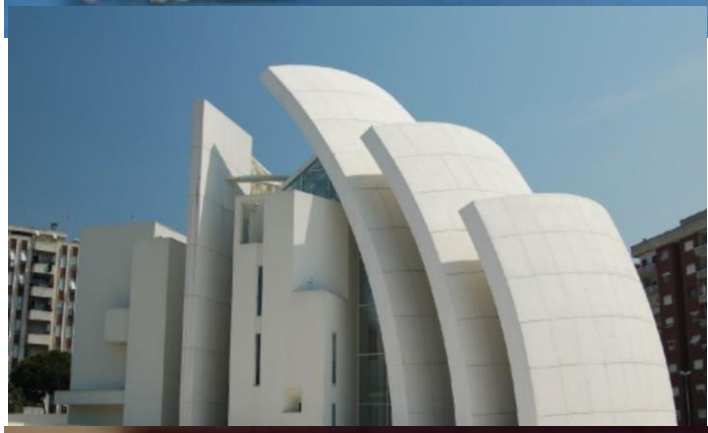
photocatalytic titanium dioxide – self-cleaning effect

Transparent concrete

utilisation of optic fibres

3D printing





Advanced structural principles

utilisation of concrete light frame in low energy buildings

- Thermal mass
- Acoustic properties
- Horizontal rigidity
- Fire safety

precast elements with integrated functions

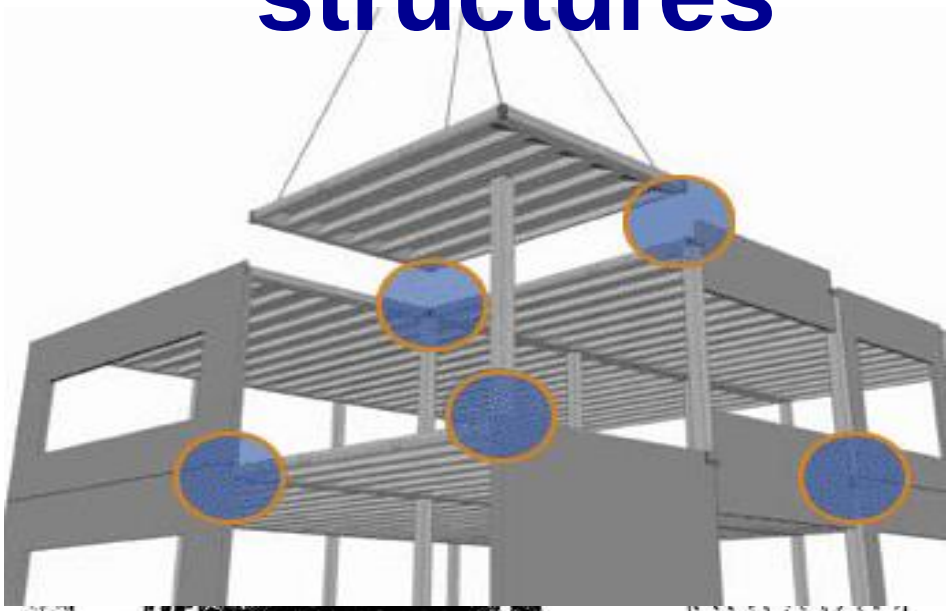
composite timber – concrete structures

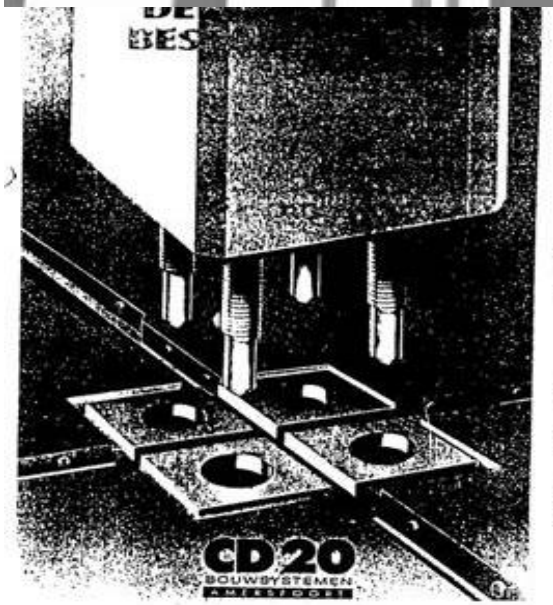
Renovation and conversion

Conversion of granery
into students hostel
Oslo - Norway

Conversion of water tower
into 40 students flats
Jaesbergborg - Denmark

Deconstruction and demountable structures





Demountable structures and reuse of components

Big Dig House
Lexington, MA | 2006, SsD architects

Prototype building demonstrating how infrastructural refuse can be salvaged and reused, the structural system for this house is comprised of steel and concrete discarded from Boston's Big Dig highway

Recycling and use of recycled materials in concrete technology

utilization of secondary materials from other industry sectors in concrete

fly ash, silica fume, slag

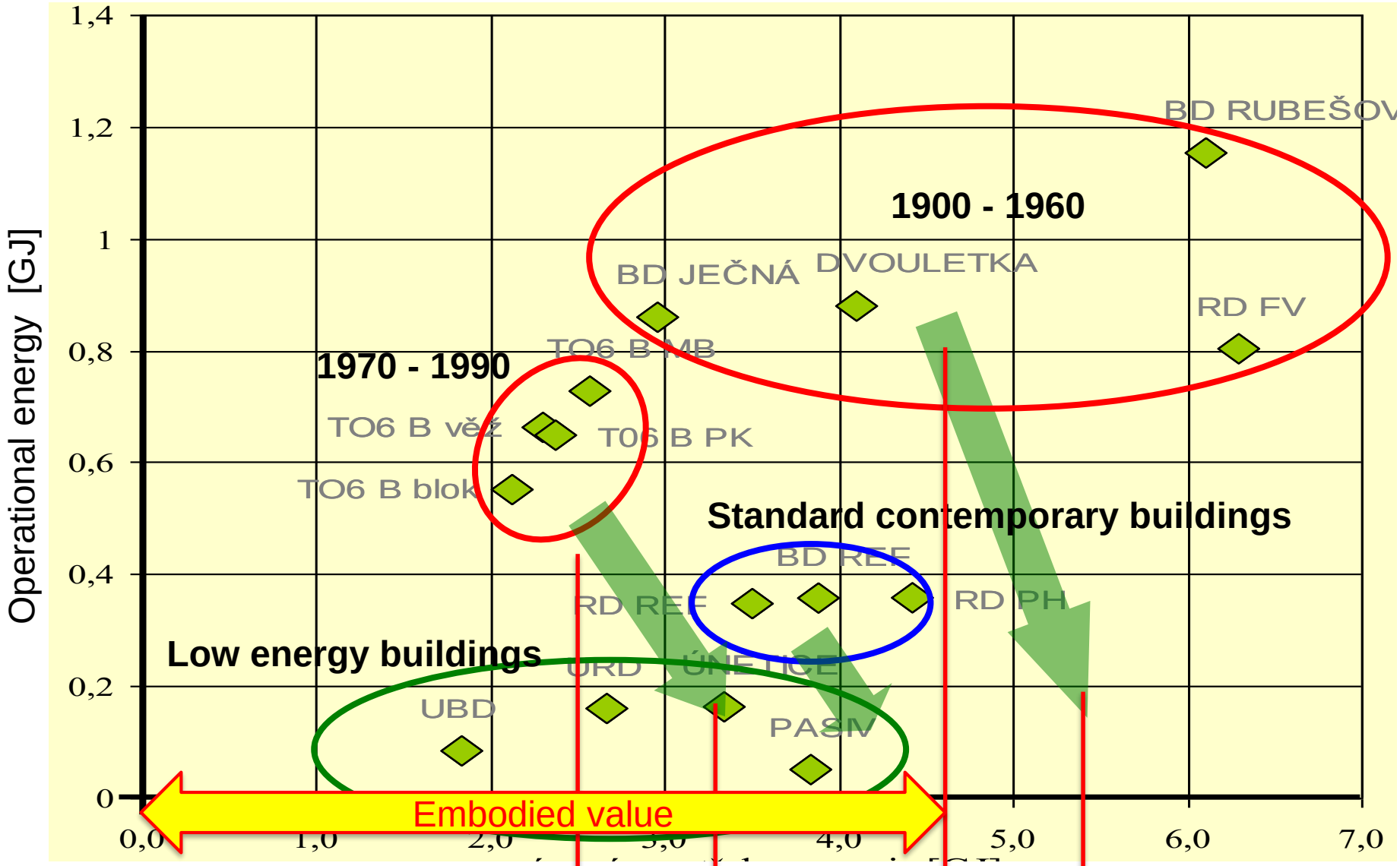
utilization of recycled concrete into new concrete

recycled gravel aggregate

utilization of recycled concrete for production of other materials

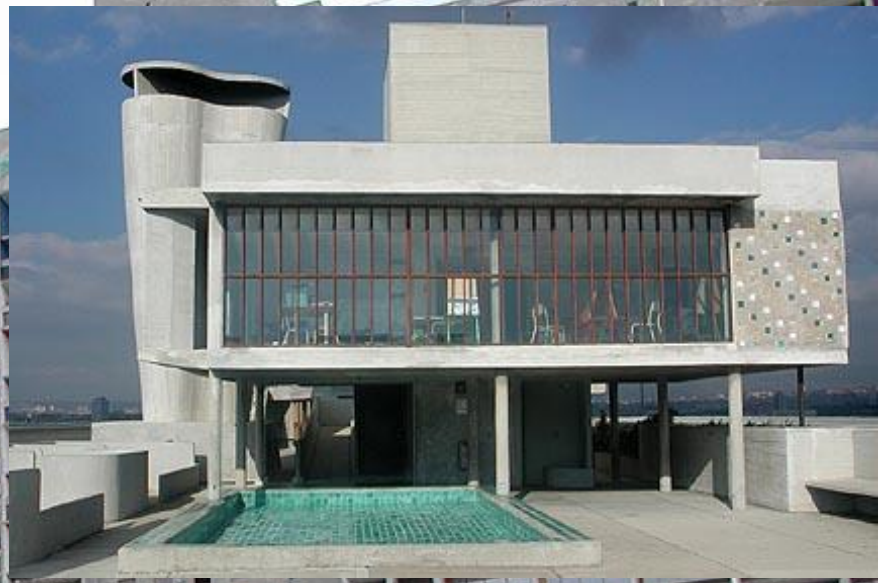
embankments

Importance of reuse and reconstruction



Source: Vonk

conceptual and integrated design



Vertical „village“ – 20 floor levels: 130 x 21 m

414 mainly mesonet flats for 1600 inhabitants

Internal shopping street, recreational area with swimming pool on the roof; kinder garden on the roof

Le Corbusier, Unite d´Habitation - Marseille

MASDAR CITY – United Arab Emirates

Clean energy: incl. power generation and storage technologies, transportation technologies, cleantech/clean energy innovation, and sustainable biofuels.

Environmental resources: including water and waste management, and sustainable agriculture technologies.

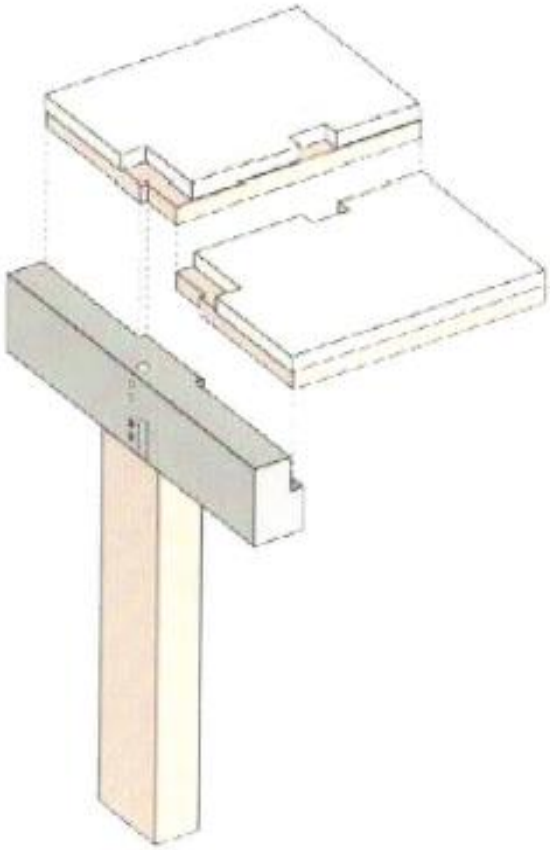
Energy and material efficiency: including developments in advanced materials, building and power-grid efficiency, and the enabling technologies.

Environmental services: including environmental protection and business services.

Bridge across Zelivka river, Vojslavice, Czech Republic

Composite RC–timber load bearing frame

Aspern – Wien - Austria



concept of light RC frame for energy efficient buildings

Petr Hájek

Concept of structural system for SB

Load bearing structure

– slender RC frame

- subtle columns from HPC
- optimised RC floor structure

Non-load bearing structures – based on renewable materials

- facade envelope and roof structure: light timber frame heavily insulated by thermal insulation
- partitions: light timber structure

Integration of load bearing structure into building envelope

Concept of structural system for SB

advantages from sustainability viewpoint

Environmental

- subtle elements – material savings
- use of recycled materials – material savings
- thermal mass of concrete structure – energy savings

Social

- high mechanical resistance and space rigidity
- fire safety
- good acoustic parameters of floor structure
- flexibility – large spans up to 9 x 9 m, flat ceiling

Economic

- fast construction - precast structural concept
- durability, easy maintenance
- design for dismounting + demountable joints

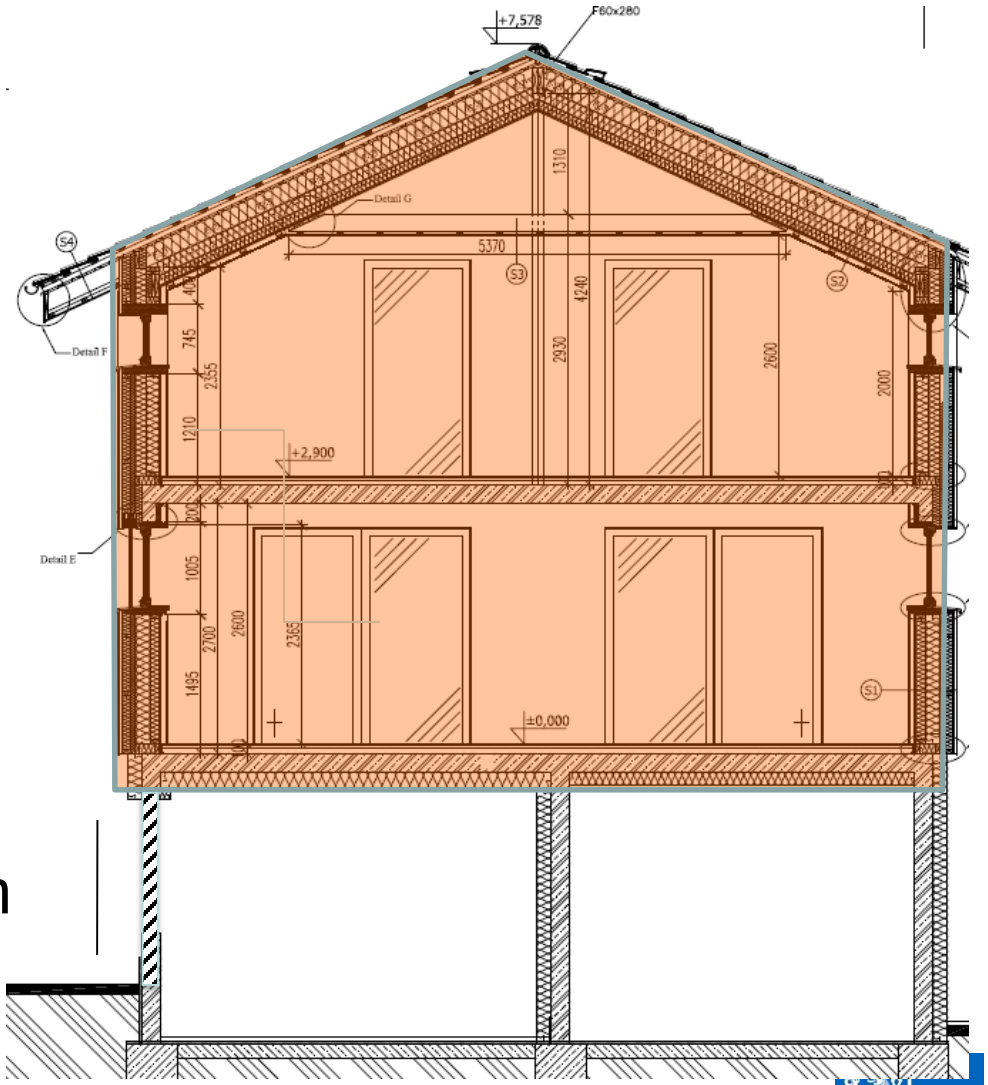
Light precast frame for passive house

Load-bearing structure:

- light RC frame from HPC
  - subtle columns
  - RC floor

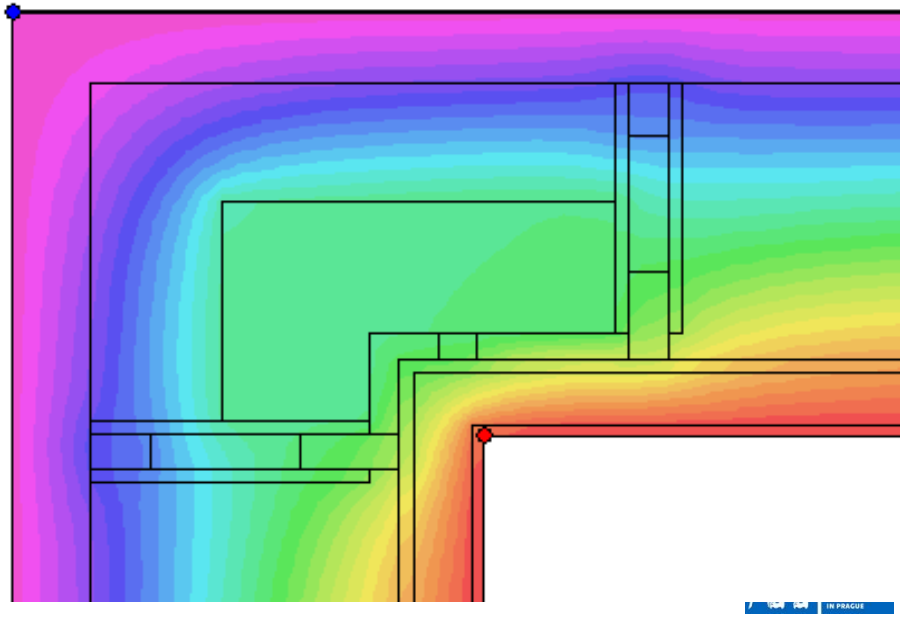
Envelope and internal partitions

- timber framed structure filled with thermal insulation



Family house in Prague Modrany

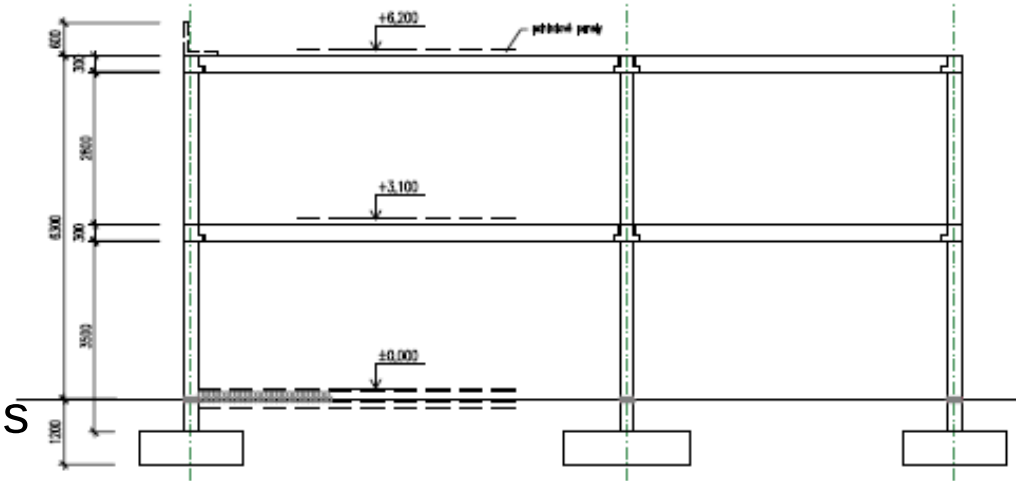
- first floor is created by subtle RC frame
- floor structures are from filigree floor system
- envelope and partitions are from timber structure
- energy passive standard

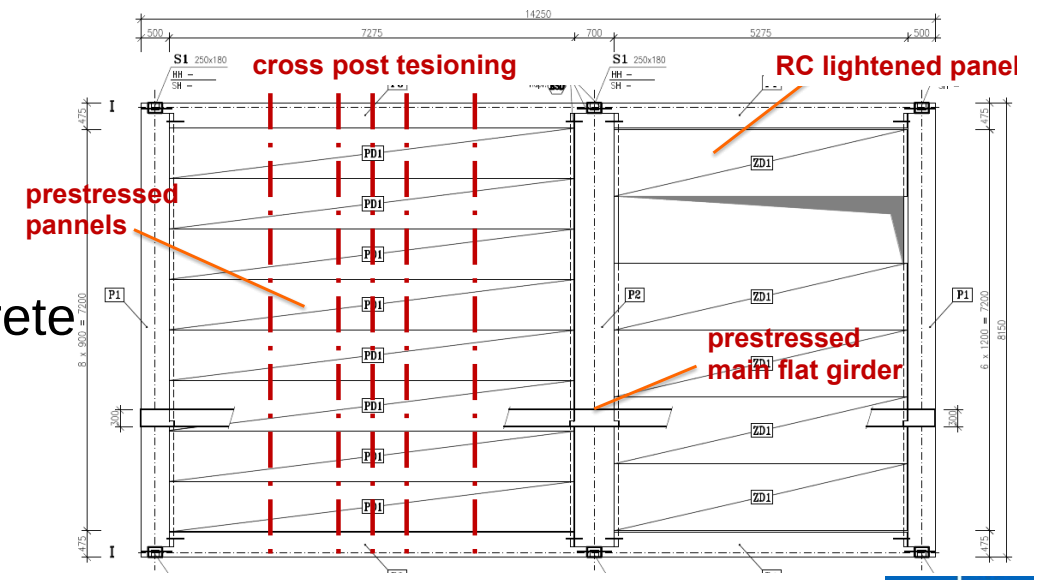


OSEEB: Precast concrete frame for SB

concept of load-bearing frame

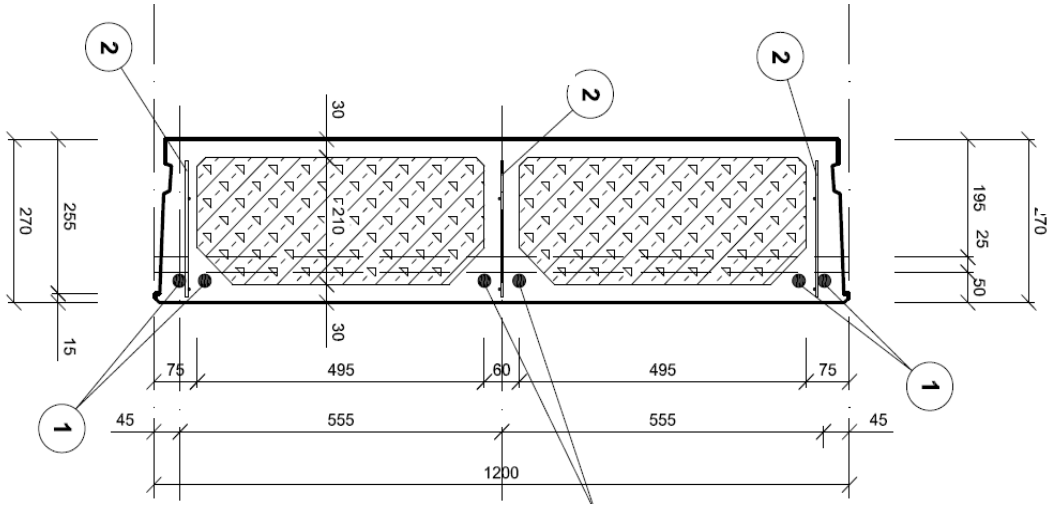
- subtle precast elements
  - use of HPC (FC 70/85)
- optimised shape of columns
  - C shape
- lightened floor panels
  - fillers from recycled materials
- flat ceiling - prestressed flat girders and floor panels
- flexibility – spans up to 9 x 9 m
  - cross post tensioning
- foundation from recycled concrete
- fast construction
- design for dismounting
  - Peikko corbels joints





Light floor panels

floor panels – optimization of lightening



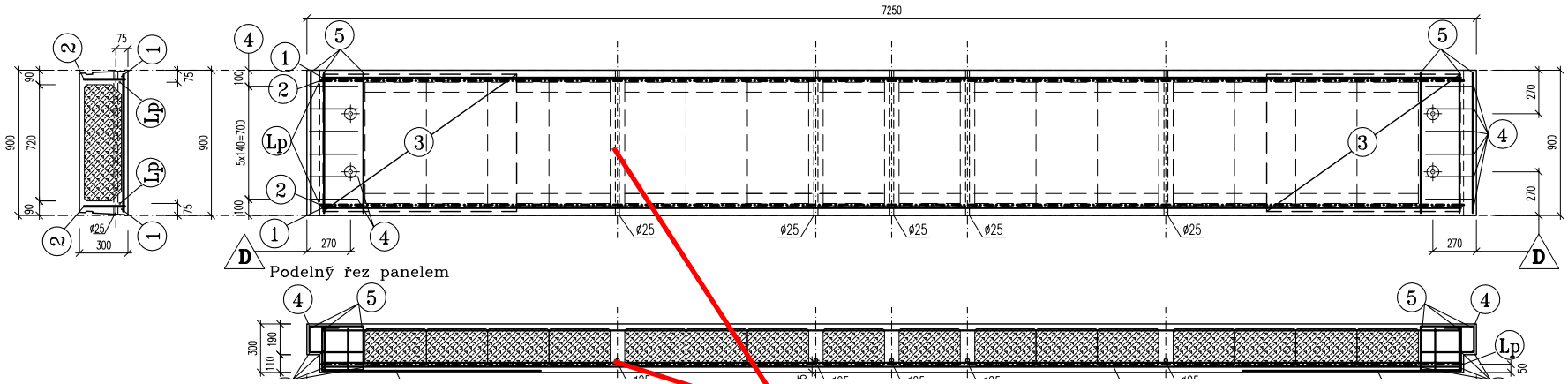
Wood shavings concrete

Stered /Stered concrete

- Weight
- Acoustic – airborn sound
- Fire safety
- Environmental impact

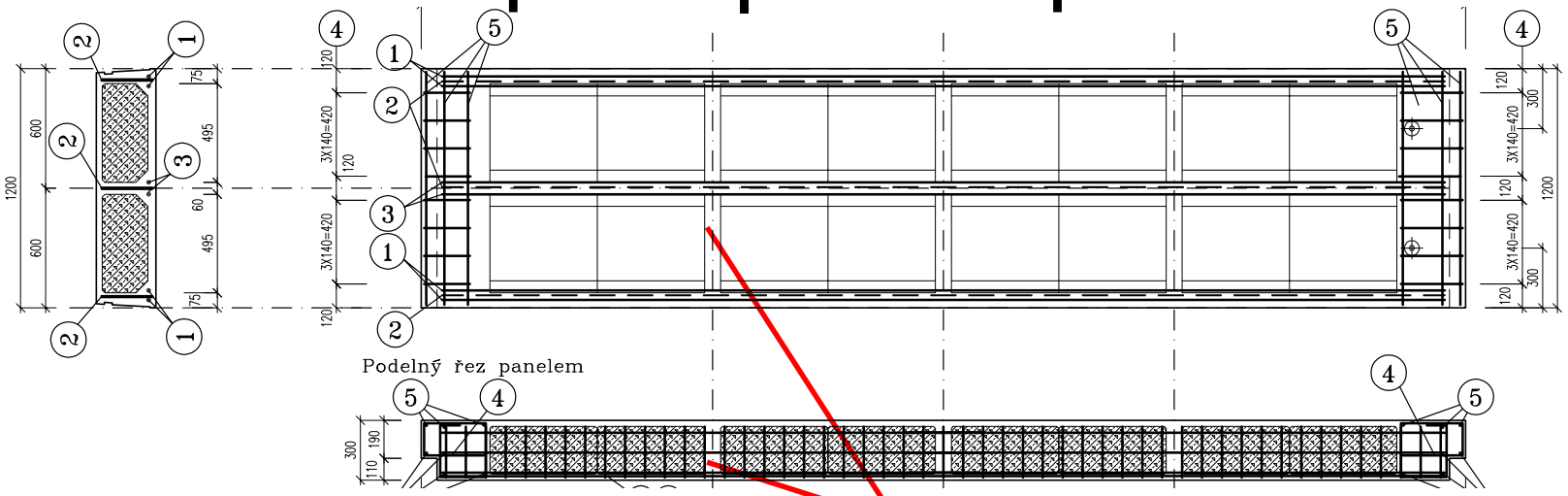
Liapor concrete

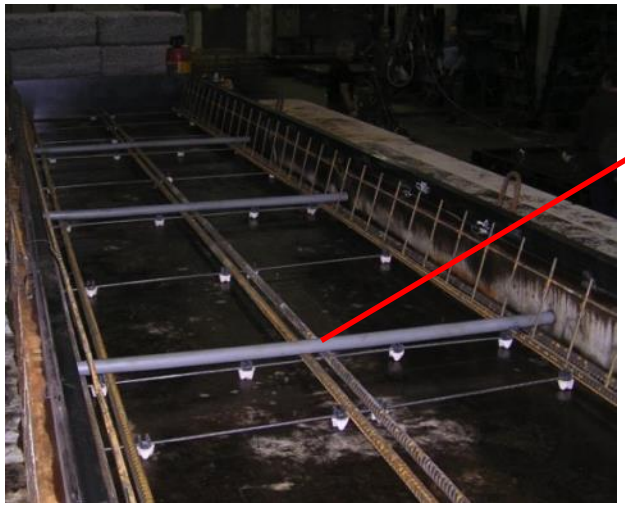
Prototype of pre-stressed floor panel



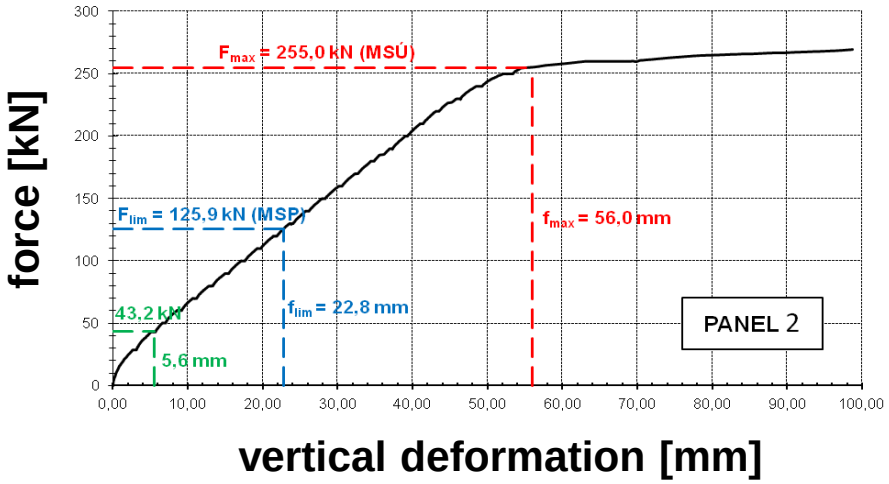
Pre-stressed floor panels

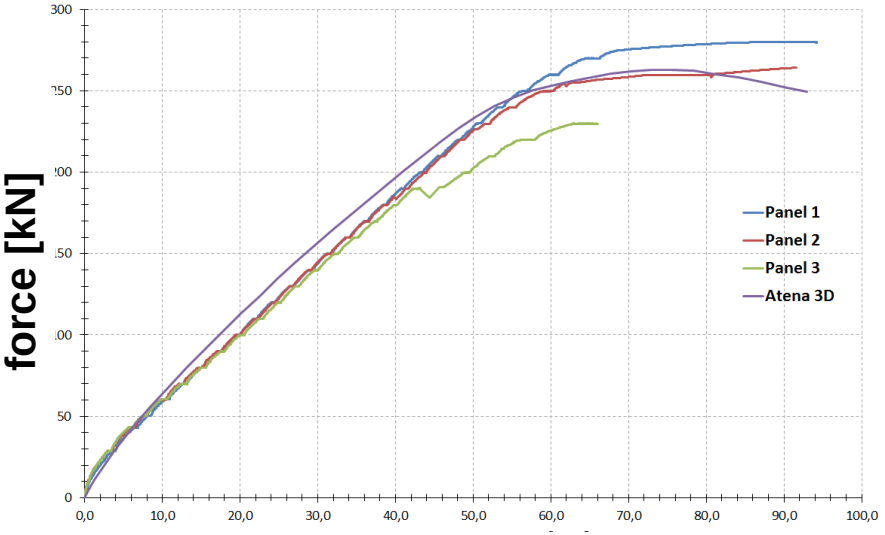
prestressed floor panels | RC floor panels





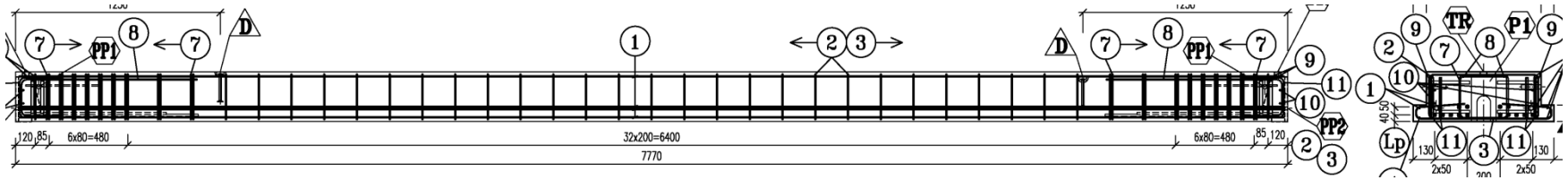
Experimental verification of floor panels



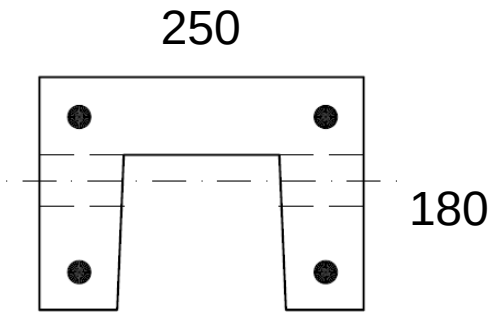


Pre-stressed floor flat girders

prestressed floor girders

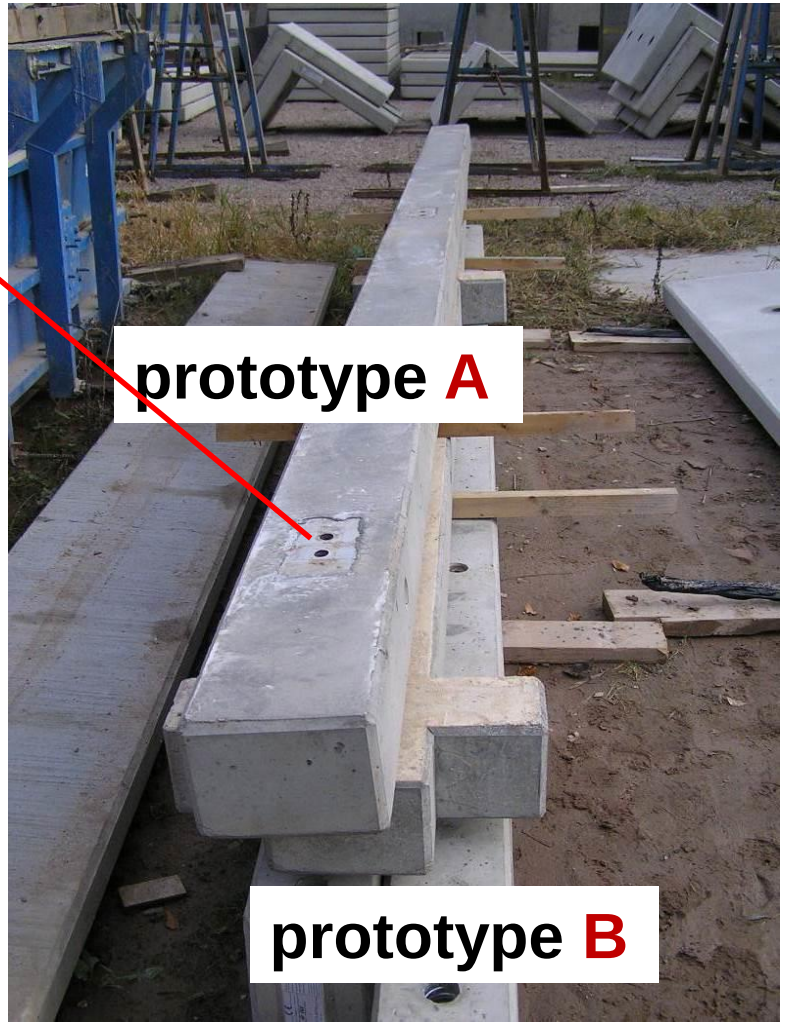


Prototypes of subtle columns



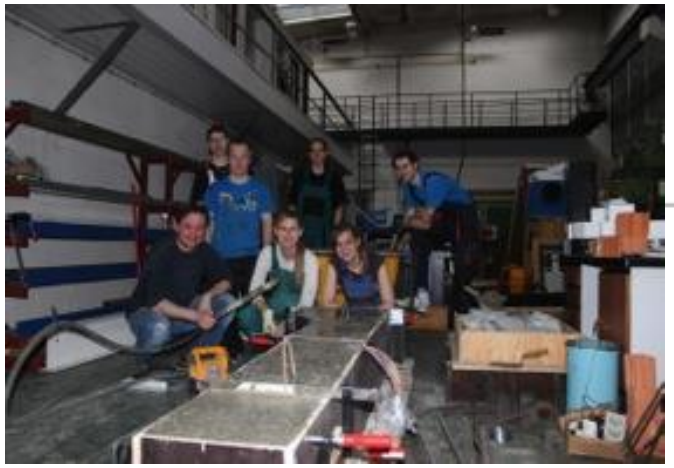
FC 70/85

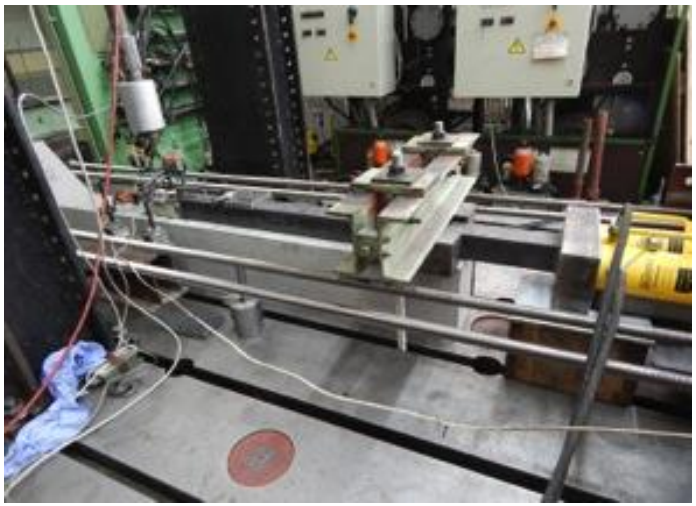
Peikko column corbel

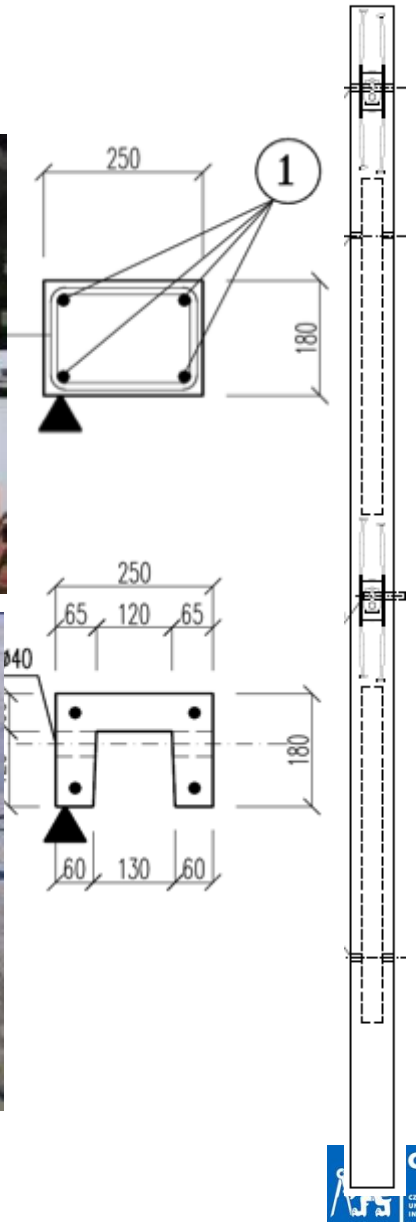


Demountable connections

RC columns with Peikko corbels







construction of experimental OSEEB frame

Construction of experimental frame

BASIC DATA

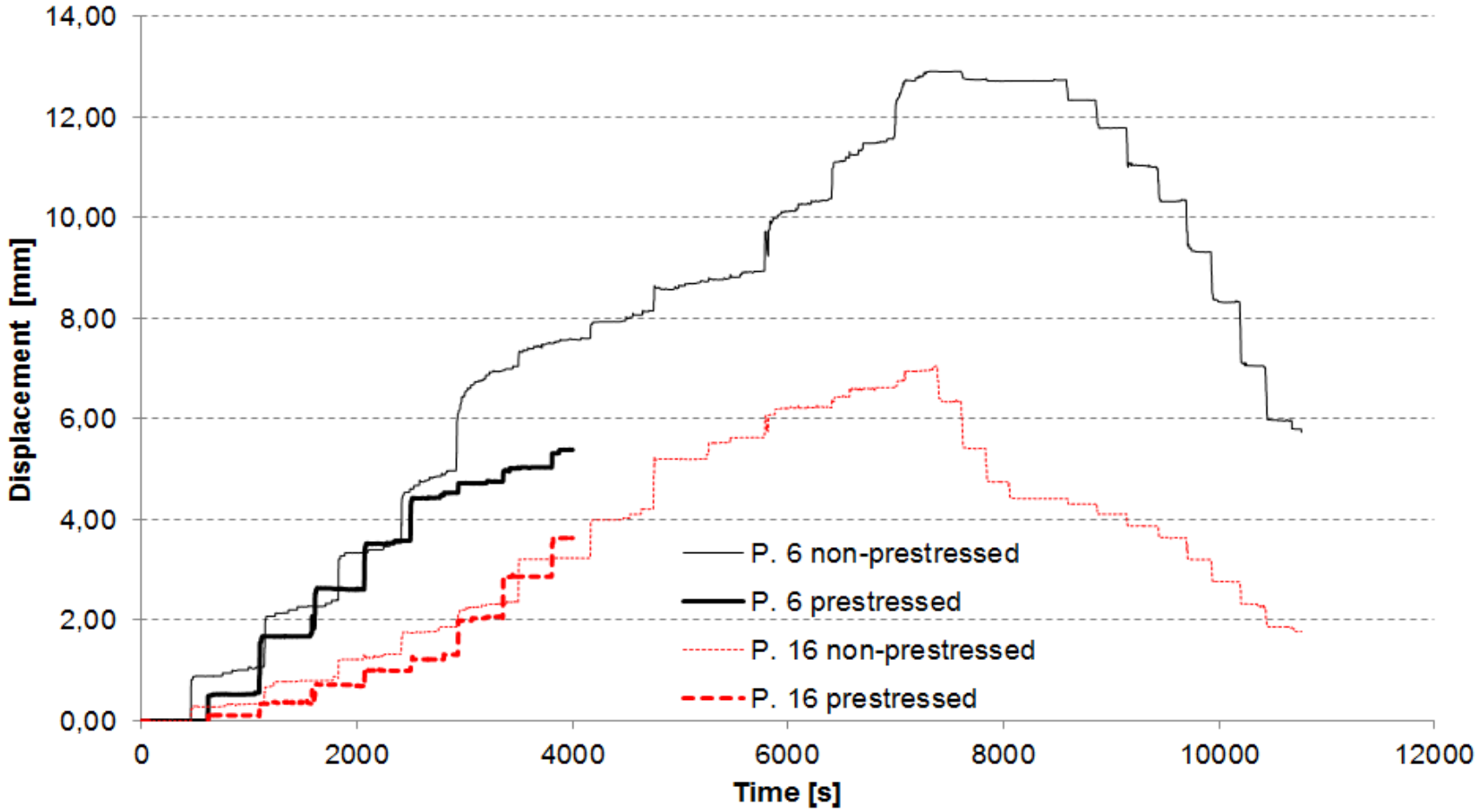
- **location:** Buštěhrad, Kladno, CTU in Prague, UCEEB
- **construction: February – April 2016**
- **load tests:** 30.06.16 a 07.07.16

Construction of experimental frame

Construction of experimental frame

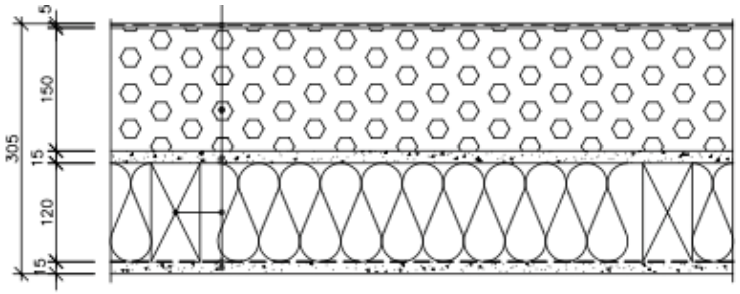
Load testing of experimental frame

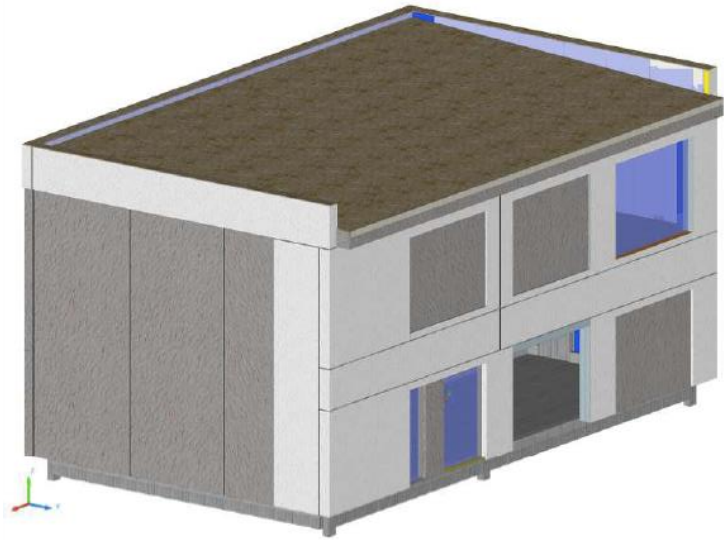
Load testing of experimental frame



Concept of prefabricated fasade

Alt. 1 timber frame fasade panels

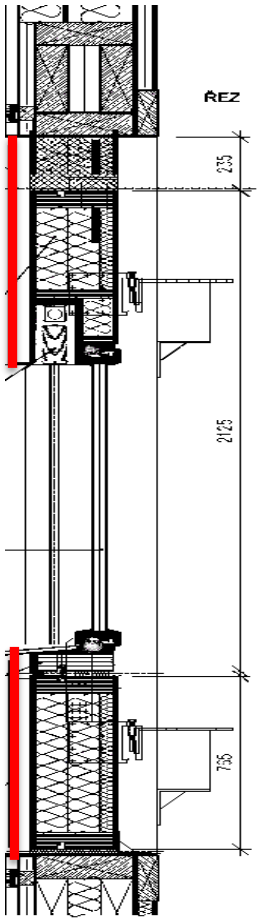


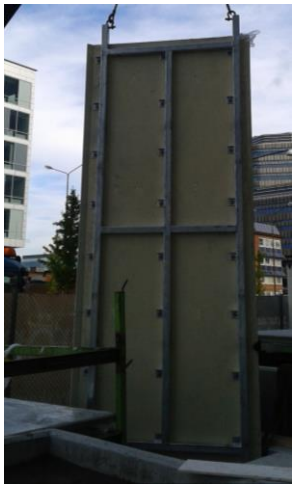


construction: July 2018

Concept of prefabricated fasade

Alt. 2
timber frame fasade panels + TRC



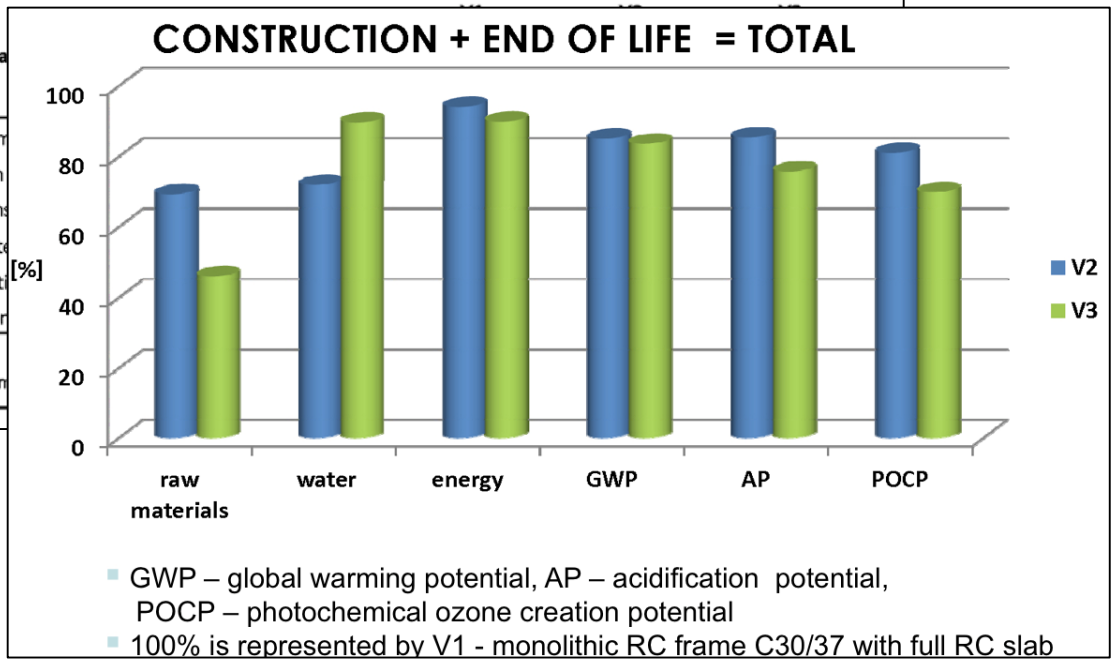


Life Cycle Assessment

CONSTRUCTION				
Balance of input data of assessment variants	unit	V1 TYPE_1_M C30/37	V2 TYPE_2_P C30/37	V3 TYP_3_P FC100/115
concretes	concrete			
	concrete			
	H-concre			
concrete components	cement			
	sand | gr			
	crushed			
	slag			
	metakao			
	micro mi			
	steel fibr			
	superpla			
	water			
other	reinforci			
	reinforci			
	wood-shavings			
	formwork | falsework			
transport	-			
	freight traffic - long-distance			
	freight traffic - local			

CONSTRUCTION				
Aggregated data of assessment variants	unit	V1 TYPE_1_M C30/37	V2 TYPE_2_P C30/37	V3 TYP_3_P FC100/115
consumption of p				
water consumpti				
primary energy c				
global warming p				
acidification pote				
photochemical o				
Note:				
1) non-renewable p				

CONSTRUCTION
END OF LIFE
CONSTRUCTION + END OF LIFE = TOTAL
Aggregated da
consumption of prim
water consumption
primary energy cons
global warming pote
acidification potenti
photochemical ozon
Note:
1) non-renewable prim



- GWP – global warming potential, AP – acidification potential, POCP – photochemical ozone creation potential
- 100% is represented by V1 - monolithic RC frame C30/37 with full RC slab

conclusions

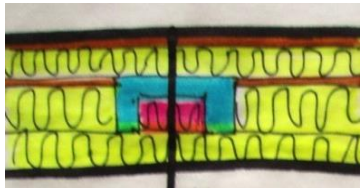
1 conclusion

- **Sustainability should become a basic concept** - an “umbrella” for high quality design and operation of concrete structures through entire life cycle – considering all three pillars – social, environmental and economic.

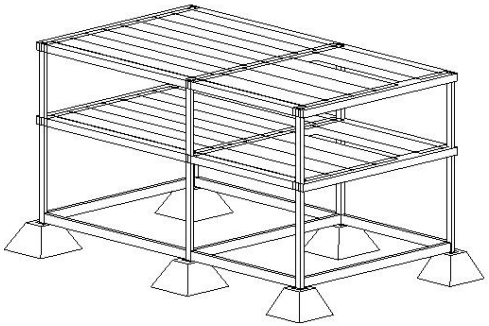
- Environmental **assessment should be solved using existing standard methodologies** of **LCA** and economic pillar using standard methodologies of **LCC**.

2 conclusion

- **precast elements from HPC / UHPC:**
  - **subtle construction - reduction of concrete use**
  - **thin façade envelope with integrated load bearing structure**



- **demountable precast structure:**
  - **dissemblance and recycling**



- **combination of concrete and timber structures:**
  - **use of renewable materials**
  - **modernisation/replacement of façade envelope in shorter periods**
- **use of recycled materials:**
  - **precast foundation elements from recycled concrete**

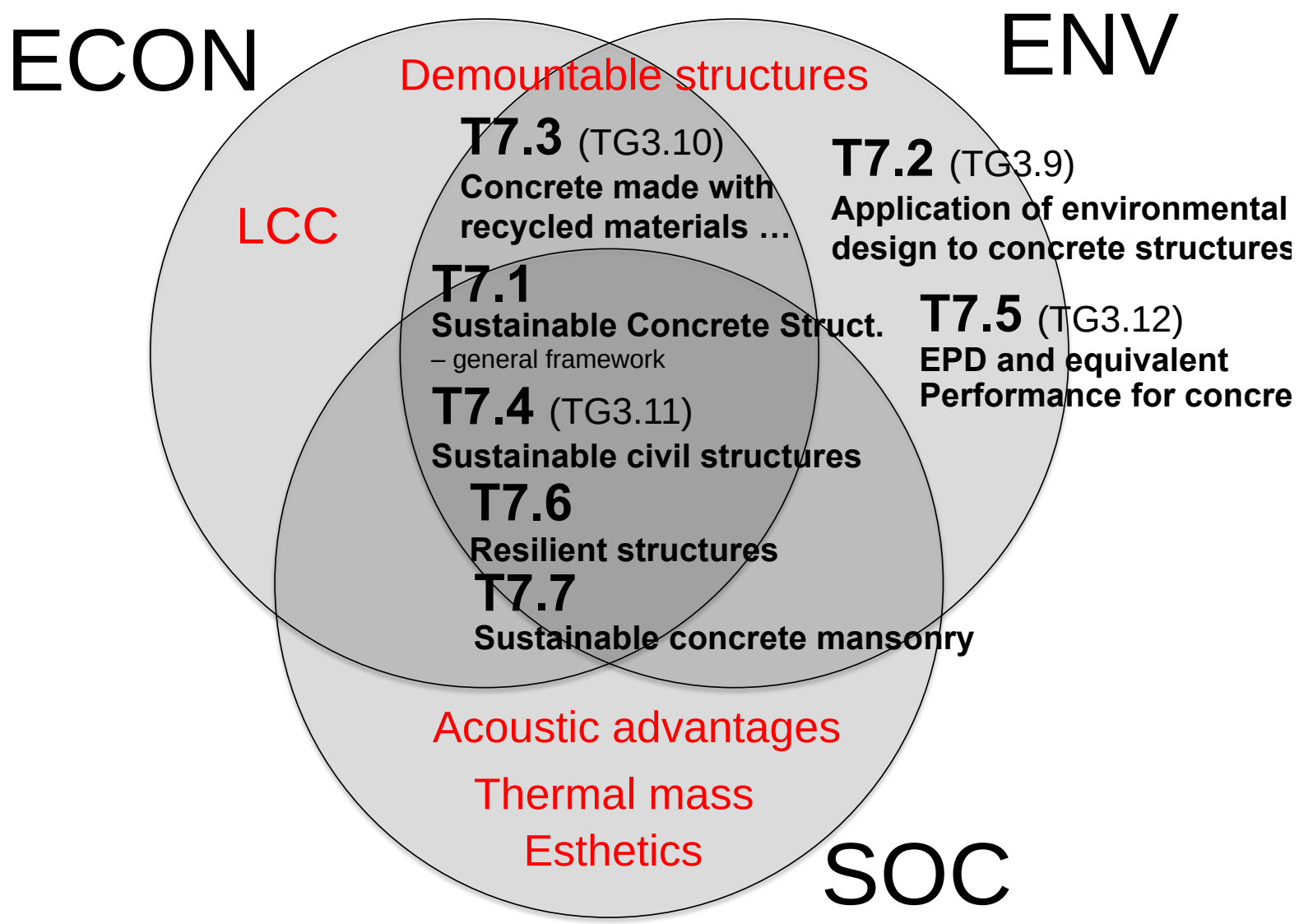
conclusion

Optimized concrete structures

using new types of concrete in advanced technologies can significantly contribute to

sustainability and **resilience**

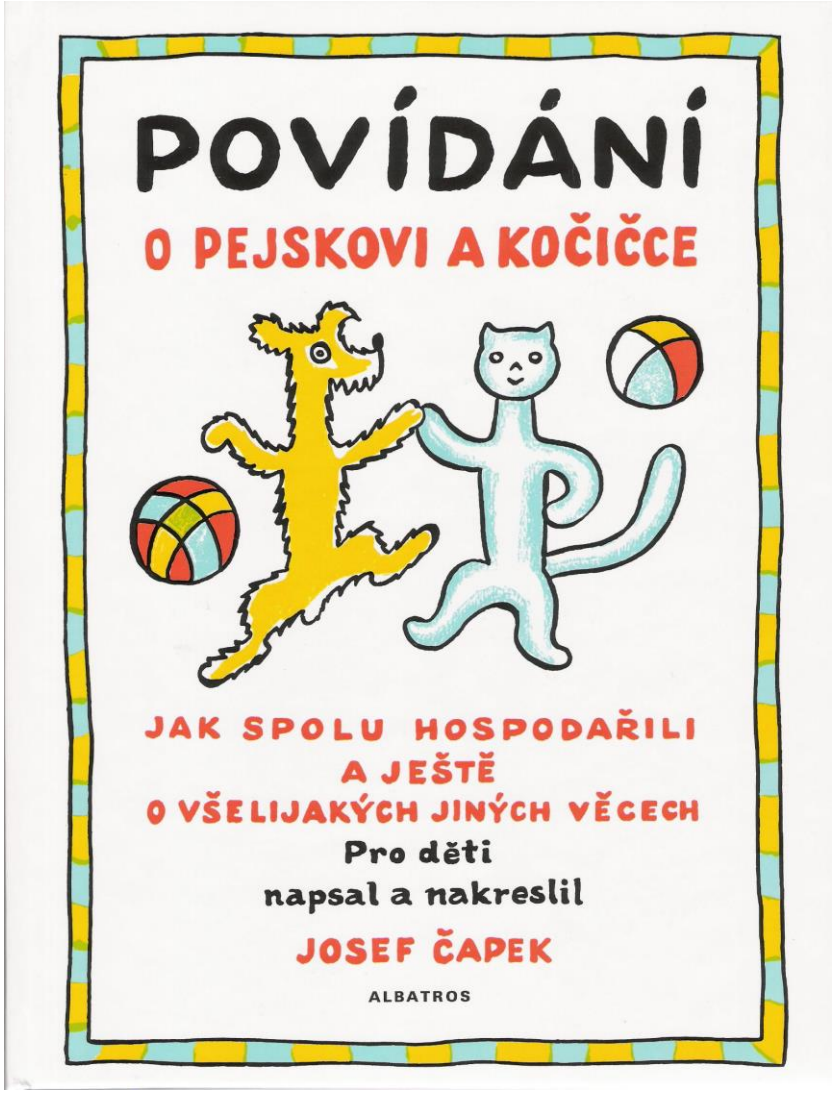
fib Commission 7 - Sustainability

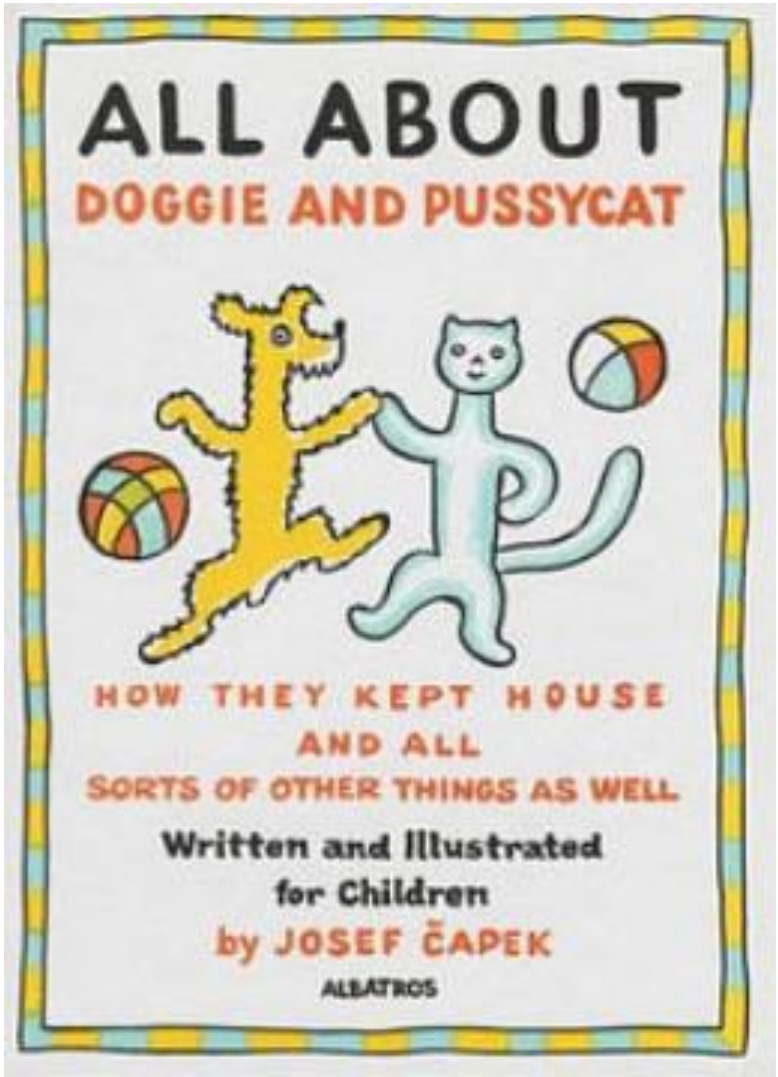



Thank you for attention
fib PhD Symposium 2018 Prague Aug. 29-31
12th *fib* International PhD Symposium
in Civil Engineering
CESB 19 Prague July 2– 4
5th International Conference
Central Europe towards Sustainable Building
fib ICCS 2020 Prague Sept. 23– 25
3rd International Conference
on Concrete Sustainability


How Doggie and
Pussycat baked a cake

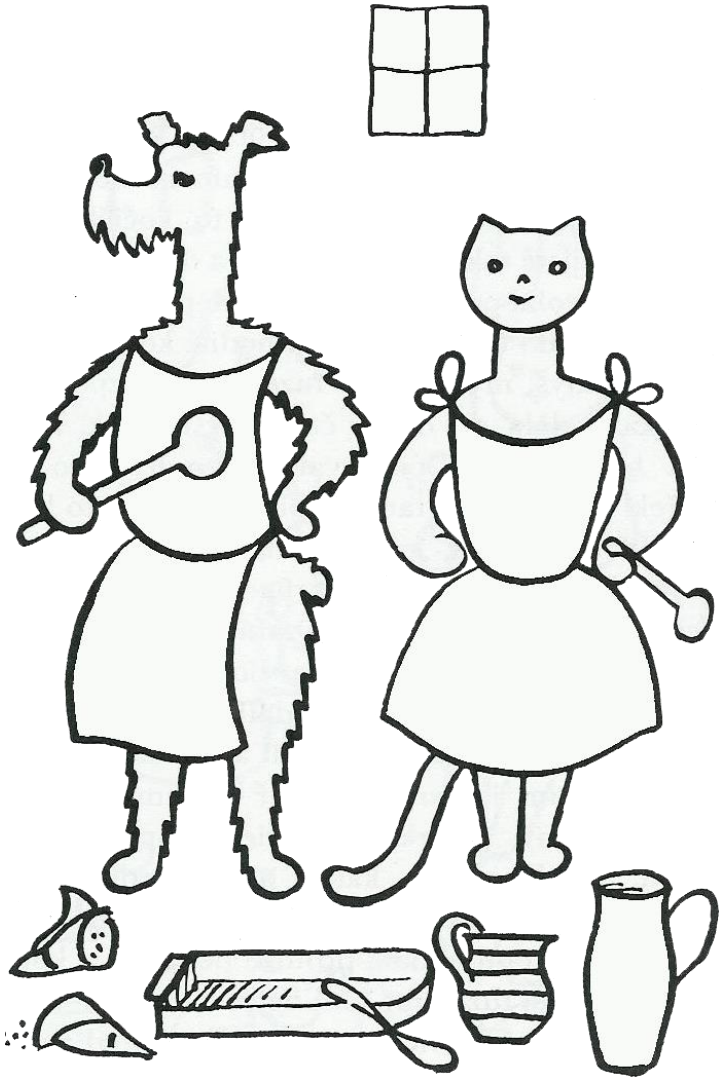
Josef Čapek


POVÍDÁNÍ
O PEJSKOVI A KOČIČCE
JAK SPOLU HOSPODAŘILI
A JEŠTĚ
O VŠELIJAKÝCH JINÝCH VĚCECH
Pro děti
napsal a nakreslil
JOSEF ČAPEK
ALBATROS


ALL ABOUT
DOGGIE AND PUSSYCAT
HOW THEY KEPT HOUSE
AND ALL
SORTS OF OTHER THINGS AS WELL
Written and Illustrated
for Children
by JOSEF ČAPEK
ALBATROS

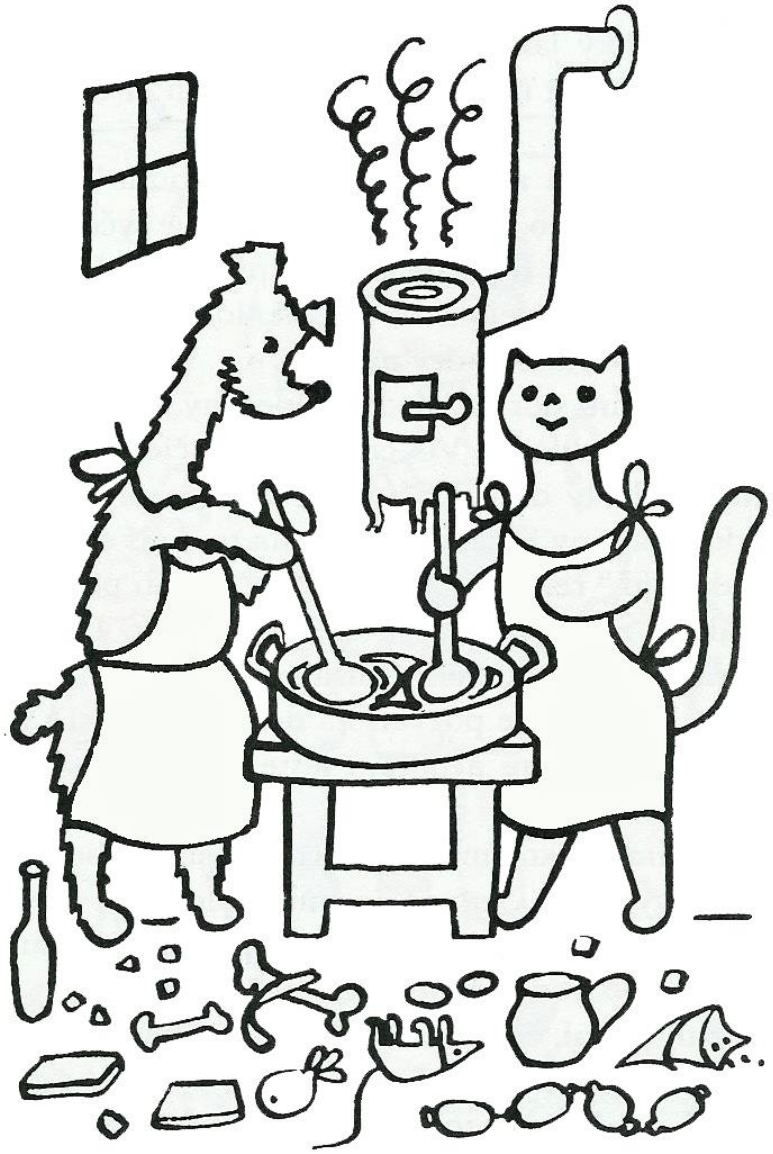
It was Doggie's birthday and Pussycat's name-day and thus they decided to make a cake

"We will put everything we like in that cake, and then it will taste the best."



They put into cake all their favourite food:

suggar, chocolate, nuts, milk, eggs, strong cheese, bacon, gherkins, cream, garlic, onion, pepper, cabbage, mouse, spicy sausages, etc.



They mixed it together and baked it in the oven……

And they put a cake outside to cool down

When Doggie and Pussycat came for a cake, they couldn’t find it.

But instead they saw a big bad dog with a stomachache.

now the lesson:

- mixing excellent components does not guarantee excellent result
- interaction of components and subsystems should be considered
- **Holistic approach considering all components their interaction and essential aspects of sustainability represents a key approach to design and construction of structures**