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: Vona

Embodied energy [GJ]
Embodied value
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

10 km²
50 000 inhabitants, 60 000 commuting
1500 firms
completion 2020 - 2025

Masdar Abu Dhabi
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
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

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

- 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

- 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

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

Wood shavings concrete
Stered / Stered concrete
Liapor concrete
Prototype of pre-stressed floor panel

tubes for transverse post tensioning
Pre-stressed floor panels

prestressed floor panels | RC floor panels

tubes for cross post tensioning
Experimental verification of floor panels

- $F_{\text{max}} = 255.0 \text{ kN (MSÜ)}$
- $F_{\text{lim}} = 125.9 \text{ kN (MSÜ)}$
- $f_{\text{lim}} = 22.8 \text{ mm}$
- $f_{\text{max}} = 56.0 \text{ mm}$

Graph showing force vs. vertical deformation for different panels.
Pre-stressed floor flat girders

prestressed floor girders

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Prototypes of subtle columns

250

180

FC 70/85

Peikko column corbel

prototype A

prototype B
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

![Graph showing load testing results for different frames.](image-url)
Concept of prefabricated façade

Alt. 1 timber frame façade panels

construction: July 2018
Concept of prefabricated facade

Alt. 2
timber frame facade panels + TRC
Life Cycle Assessment

CONSTRUCTION

Balance of input data of assessment variants

<table>
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<th>V1</th>
<th>V2</th>
<th>V3</th>
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<td>TYPE_2_P &amp; TYPE_3_P</td>
<td>TYPE_3_P &amp; FC100/115</td>
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<td>freight traffic - long-distance</td>
<td>freight traffic - local</td>
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</table>

Note: 1) non-renewable primary energy

CONSTRUCTION + END OF LIFE = TOTAL

- 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
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**.
• 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
Optimized concrete structures
using new types of concrete in advanced technologies can significantly contribute to sustainability and resilience
fib Commission 7 - Sustainability

LCC

T7.1
Sustainable Concrete Struct. – general framework

T7.3 (TG3.10)
Concrete made with recycled materials ...

T7.4 (TG3.11)
Sustainable civil structures

T7.6
Resilient structures

T7.7
Sustainable concrete masonry

Acoustic advantages

Thermal mass

Esthetics

Demountable structures

ECON

ENV

SOC

Resilient structures

Sustainable concrete masonry

Application of environmental design to concrete structures

EPD and equivalent Performance for concrete

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CO

CONCER

T7.2 (TG3.9)

T7.5 (TG3.12)

T7.6
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

POVIDÁNÍ
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

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Petr Hájek
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