Fibre Reinforced Concrete – fib T4.1
From *opus caementicium* to concrete

Pantheon (-27 à 125)
From cement...

J. Smeaton

L. Vicat

... J. Aspdin (ciment Portland) ...

1756

1818

1824

1855
[ Problem with concrete ]:

- **Compression**
- **Tensile strength**
- **Ductility**
...to (prestressed) reinforced concrete
Straw as reinforcement: «Adobe»
But vegetal fibres have limitations.
My invention (...) consists in a composition formed by mixing two parts of coarse gravel, two parts of sand, two parts of hydraulic lime, and one part of any granular waste iron, (...)

Steel (fibres) as reinforcement

A. Berard
Standardized design methods starting from 1995

Dramix Guidelines
Infrastructuur in het leefmilieu 4-95

Rilem TC162-TDF
Test and design methods for SFRC

EC2 Building Code
Kick-off meeting

fib Model Code
for Concrete Structures
2010

1995
2003
2012
2013
Océanographic Museum (Valencia, Spain)
Architect: F. Candela

50 kg/m³  6 cm

Secundary reinforcement
Ultra-High Fibre Reinforced Concrete (UHPC) (2-4% micro-fibres – fc ~150 MPa)
Is this reliable?
fib MC 2010

1. Scope
2. Terminology
3. Basic Principles
4. Principles of structural design
5. Materials
6. Interface characteristics
7. Design
8. Construction
9. Conservation
10. Dismantlement, recycle and reuse
fib MC 2010

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5.1. Concrete
5.2. Reinforcing steel
5.3. Prestressing steel
5.4. Prestressing systems
5.5. Non-metallic reinforcement
5.6. Fibres / fibre reinforced concrete

Joint chapters prepared by fib TG 8.3 "Fiber reinforced concrete" and fib TG 8.6 "Ultra high performance fiber reinforced concrete"

7.7. Verification of safety and serviceability of FRC structures
Post-peak behaviour (fibres only)…

Softening material

Hardening material
Test methods (mainly used)

*Direction tension (RILEM)*

*3-pt bending (EN 14651)*

*Round determinated plates (ASTM C1550)*
Diameter 800 mm
Thickness 75 mm
3 supports
MC 2010 Performance classes

Characterization in 3-pt bending (EN 14651)

Load

\[ F_{R,1} \]

\[ F_{R,3} \]

Crack opening [mm]

L = 500 mm

\( h_{sp} = 125 \text{mm} \)
MC 2010 Performance classes

Class 2a

\( f_{R1,k} \text{ [MPa]} \)

- **a** : \( 0.5 < \frac{f_{R3,k}}{f_{R1,k}} < 0.7 \)
- **b** : \( 0.7 \leq \frac{f_{R3,k}}{f_{R1,k}} < 0.9 \)
- **c** : \( 0.9 \leq \frac{f_{R3,k}}{f_{R1,k}} < 1.1 \)
- **d** : \( 1.1 \leq \frac{f_{R3,k}}{f_{R1,k}} < 1.3 \)
- **e** : \( 1.3 \leq \frac{f_{R3,k}}{f_{R1,k}} \)
Minimum ductility (structure)

Ductility provided by the material (FRC/Rebars)

Ductility provided by the structural redundancy

\[ \delta_u \geq 20 \delta_{SLS} \]

OR

\[ \delta_{peak} \geq 5 \delta_{SLS} \]

Diagram showing:
- Load (P) vs. Displacement (\(\delta_u\))
- Maximum Load (P_{MAX})
- Ultimate Load (P_{U})
- Load at crack formation (P_{cr})
- Load at SLS (P_{SLS})
- SLS Displacement (\(\delta_{SLS}\))
- Peak Displacement (\(\delta_{PEAK}\))
- Total Displacement (\(\delta_{u}\))
Reliability

Influence of orientation $f_{Ftd,mod} = f_{Ftd}/K$

L. Ferrara et al. (2010)
Reliability

Redistribution coefficient \((K_{Rd})\)

\[ P_{Rd} = K_{Rd} \cdot P(f_{Fd}) \]

\[ K_{Rd} \left( \frac{V}{V_0}, \frac{P_{max}}{P_{cr}} \right) \]

Max load

Cracking load
1. Introduction
2. Fundamentals
3. Materials
4. Mechanical properties
5. Background of design approaches
6. Background of rules in ULS and SLS
7. Durability (with or without ordinary reinforcement)
8. Severe loading conditions (blast, fire)
9. Technological aspects
10. Structural rehabilitation
11. Design examples and back calculations of full scale tests
12. Seismic resistance

FRC Bulletin (background document)

NEW BULLETIN BY 2017
Fibres for concrete...

Material
- Steel fibres
- Polymeric fibres (PP, PAN, PE, Aramid, PVA)
- Inorganic and mineral fibres (AR glass, basalt, carbon)
- Natural fibres
- Blends/Cocktails
Test results vs. predictions

- The models are (too?) safe
- Logically, a better match is found for $a/d=2.5$ (solid marks)

Test set-up
4-point bending tests on beams

- 2 $a/d$ (0.5/1.5 & 2.5)
- 2 beams by composition

=> 28 beams in total

$V_{Rdm,exp}$ [kN]

$P_{Rm,3}$ [MPa]
Support design assumptions by (full-scale) testing
Concentrated loads

Loadcell

Jack
Published papers

**On the reliability of design approach for FRC structures according to Model Code 2010: the case of elevated slabs**

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Abstract

This paper focuses on the reliability of the design approach proposed in Model Code 2010 for the estimation of the ultimate capacity of fibre-reinforced concrete (FRC) elevated slabs on the basis of different tests for material characterization. The fracture properties of the material are determined through three-point bending tests on notched slabs prepared from a concrete containing microsilica. The material properties are then used for the verification of the reliability of the design approach.