



UHPFRC:

De los componentes a la estructura

Serna Ros, Pedro;
López Martínez Juan Ángel;
Camacho Torregrosa, Esteban

Universitat Politècnica València





9 d'octubre

- Día de la Comunitat
- Sant Donis
- la Mocaorà



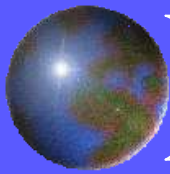
Comunitat Valenciana



Moncofa

València





9 d'octubre



Festes d'octubre
en Moncofa



ISILAMCAA
I SIMPÓSIO LATINO AMERICANO SOBRE CONCRETO AUTOADENSÁVEL
08 a 10/10 de 2012 - Macapá/EL





UHPFRC:

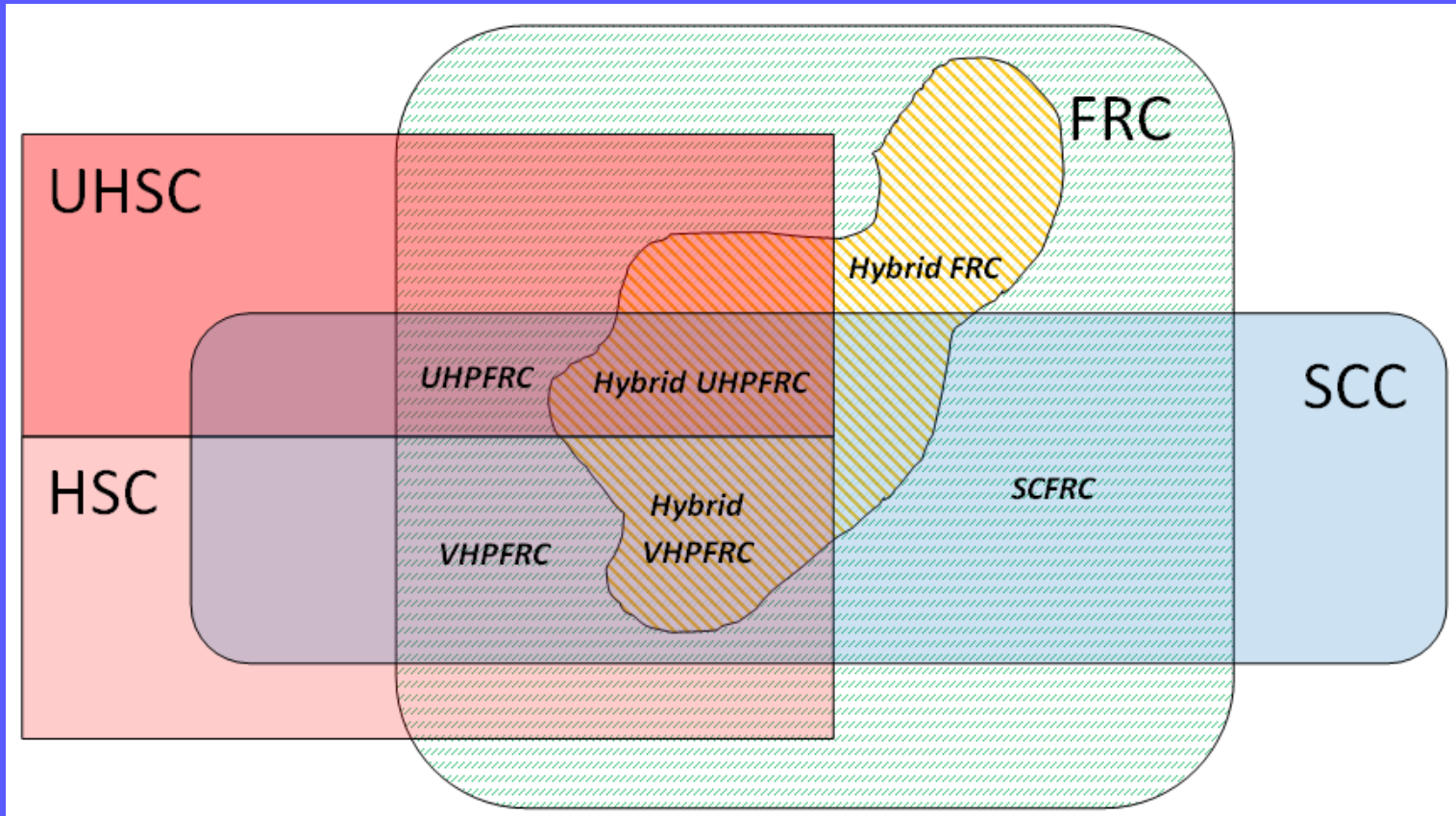
De los componentes a la estructura

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What is UHPFRC?



Diferentes familias de hormigones entorno al UHPFRC

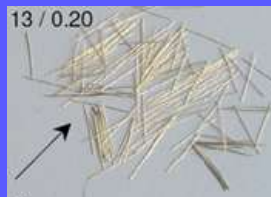
What is UHPFRC?

Dosages

- ⊕ ↑ cement and silica fume
- ⊕ ↓ ↓ W/C ratio
- ⊕ ↑ % of steel fibers, ↑ tensile strength
(¿Hybrid?)
- ⊕ **selected aggregates**, ↓ maximum diameter
- ⊕ High capacity theory -- Ultra Fines
- ⊕ Last generation admixtures

Requirements

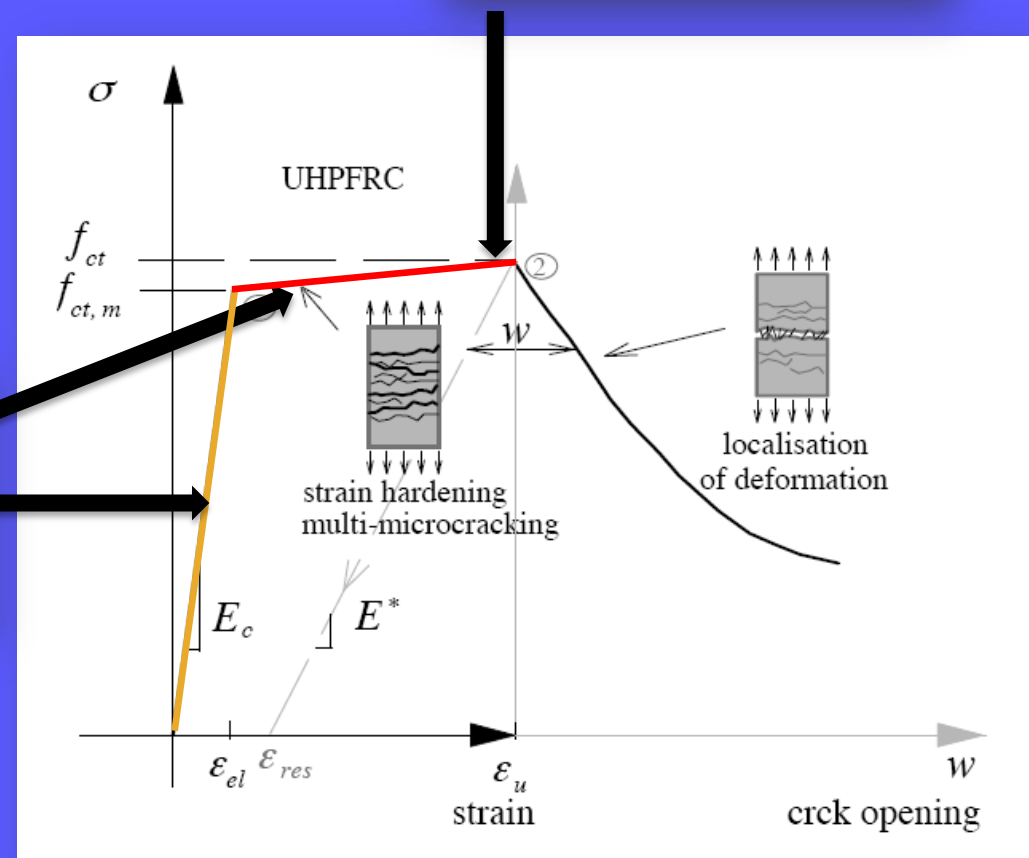
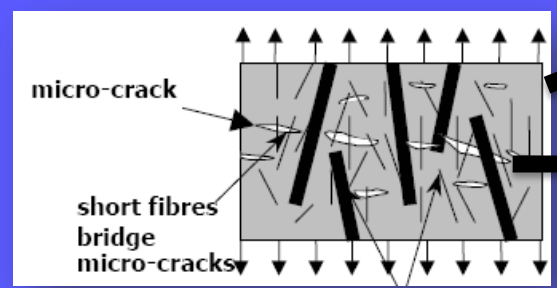
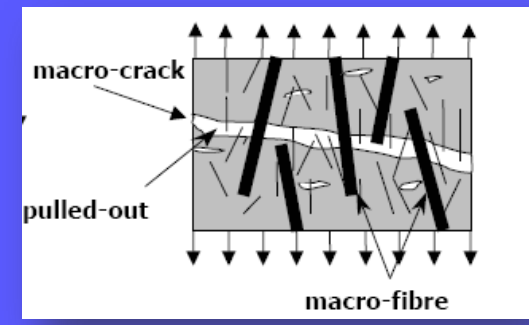
- ⊕ Requires ↑ intensive mixer
- ⊕ ↑ mixing times
- ⊕ **Steam Curing (op)**



What is UHPFRC?

Properties of Hybrid UHPFRC:

- ↑ ↑ compression and tensile strength
- Small cracks during the strain-hardening
- ↑ ductility/toughness
- ↑ Durability
- ↑ Young's modulus
- ↑ ↑ Abrasion and impact resistance





Productos Comercializados / Estudios



Material	Cemento por m3	Tipo y forma de las fibras	Cantidad de fibras	H. de sílice por m3	Tamaño máximo mm
HMAR con fibras	910 Kg	l=13 mm, d=0,16 mm	125 Kg	60 Kg	1,0
BSI/CERACEM	1107 Kg	l=20 mm, d=0,30 mm	195 Kg	165 Kg	7,0
HMAR con fibras	358 Kg CEM I, 555 Kg CEM III	l=13 mm, d=0,16 mm	125 Kg	61 Kg	2,0
HMAR híbrido	996 Kg CEM III/A 52,5 N	Cortas: 13/0,2 mm Largas 60/80	39 Kg cortas, 79	32 Kg	0,5
HMAR	583 Kg CEM I HS/NA	l=8 mm, d=0,175 mm	196 kg	178 Kg	8,0
RPC	1300 Kg, sin C3A	l=12 mm, d=0,1 mm	79 Kg	325 Kg	0,5
Ductal	712 Kg	l=12,7 mm, d=0,2 mm	156 Kg	231 Kg	0,6
HMAR con fibras	832 Kg	l=17 mm, d=0,25 mm	192 Kg	135 Kg	1,0
HMAR con fibras y áridos gruesos	723 Kg	l=17 mm, d=0,25 mm	192 Kg	118 Kg	8,0



BCV



Los productos comercializados ---- **Muy Caros**

EJEMPLOS



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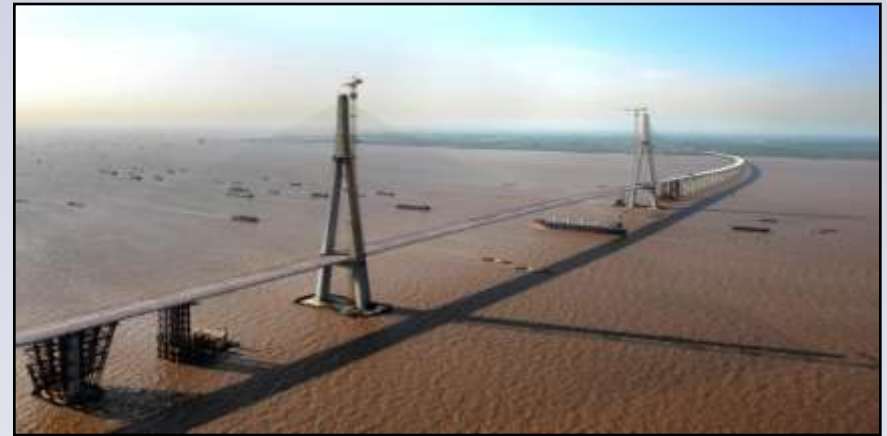
Suyungdo pasarela, Seoul Korea. 2002.



Peaje en el viaducto de Millau, Francia, 2007.



Escalera con láminas de 30 mm de espesor.



Puente en Sutong, China. 2008

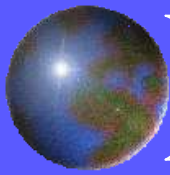
EJEMPLOS



„Opernturm“
Frankfurt / Germany



bóvedas prefabricadas con UHPC “Ductal”.
Parada de tren, Shawnessy, Canada, 2003.

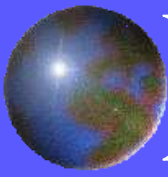


Objetivos



UHPFRC

- Exponer nuestra experiencia (2008 – 2012)
- Analizar la bibliografía
- Dar las bases para diseñar
 - el material – Diseños propios
 - estructuras
- Demostrar que es viable
- Animar a su uso e investigación



Objetivos



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Yes we can



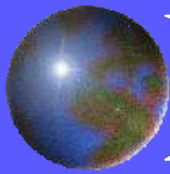
Diseño de dosificaciones

Bibliografía

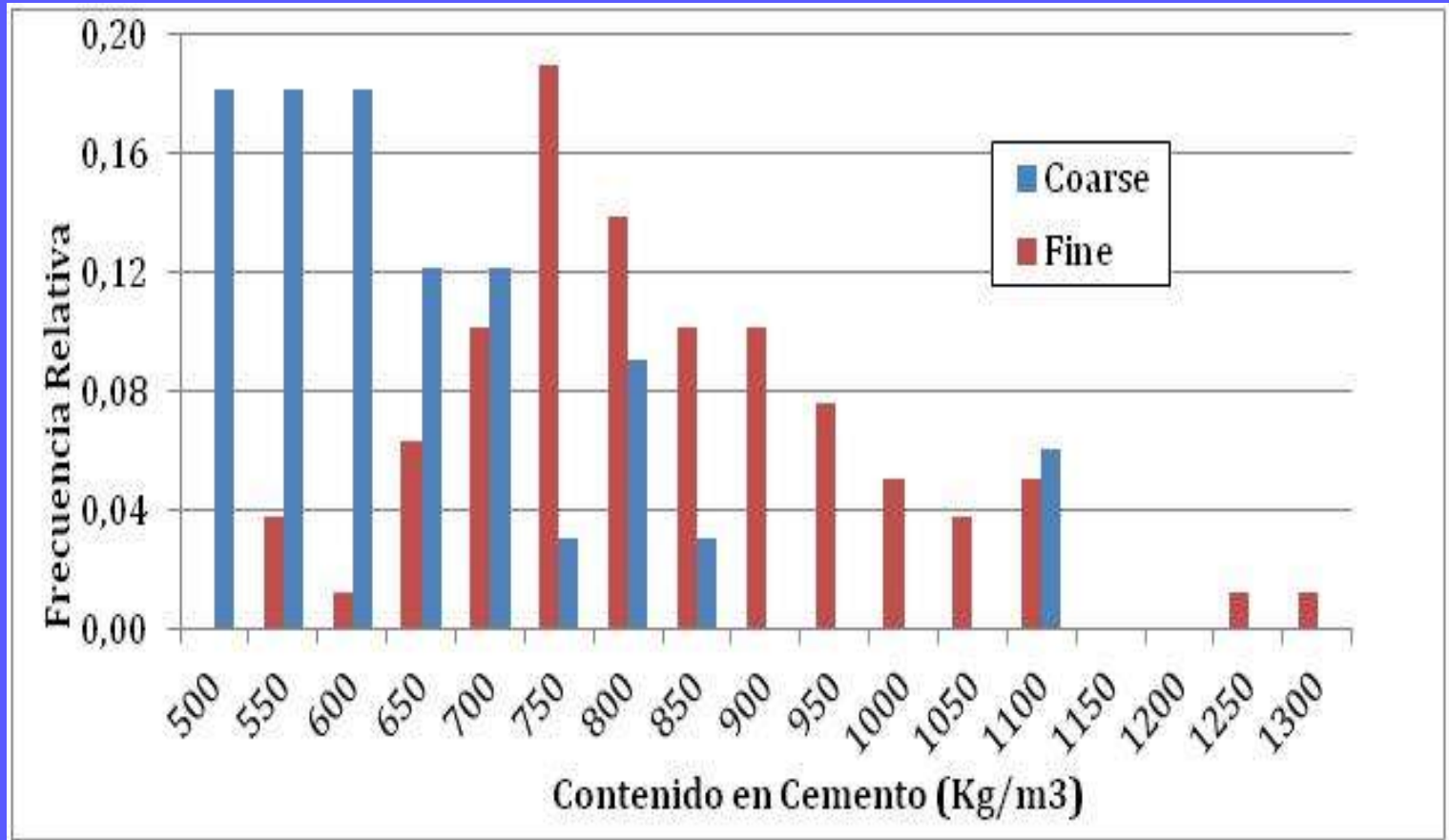
110 Dosificaciones de la bibliografía

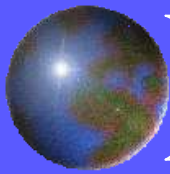
- Alto contenido en cemento
- Baja relación W/C
- Cementos de bajo AC_3
- Uso de adiciones (HdS, Cenizas, Ultra finos. etc)
- Granulometría Controlada
 - Con árido grueso
 - Sin árido grueso



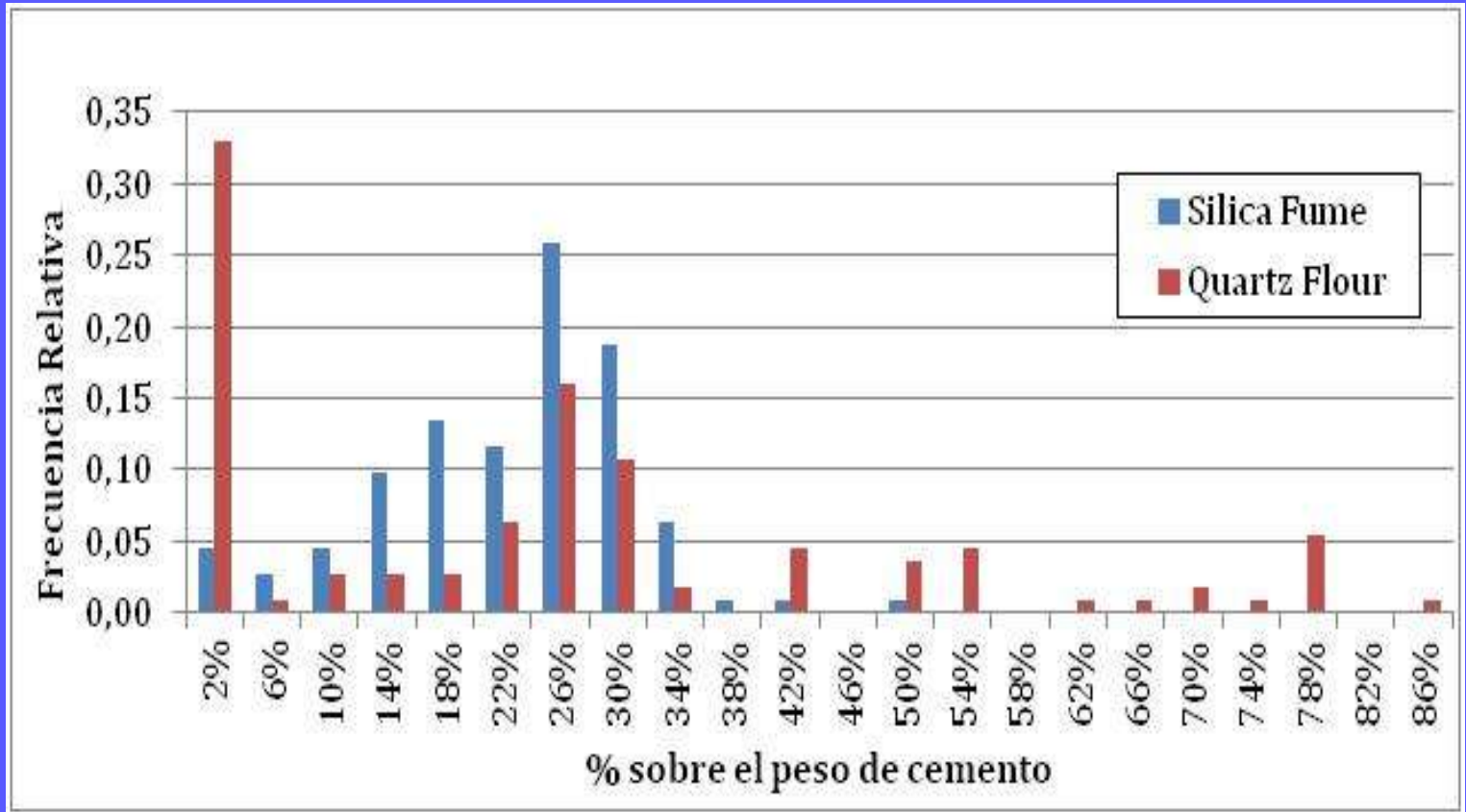


Diseño de dosificaciones

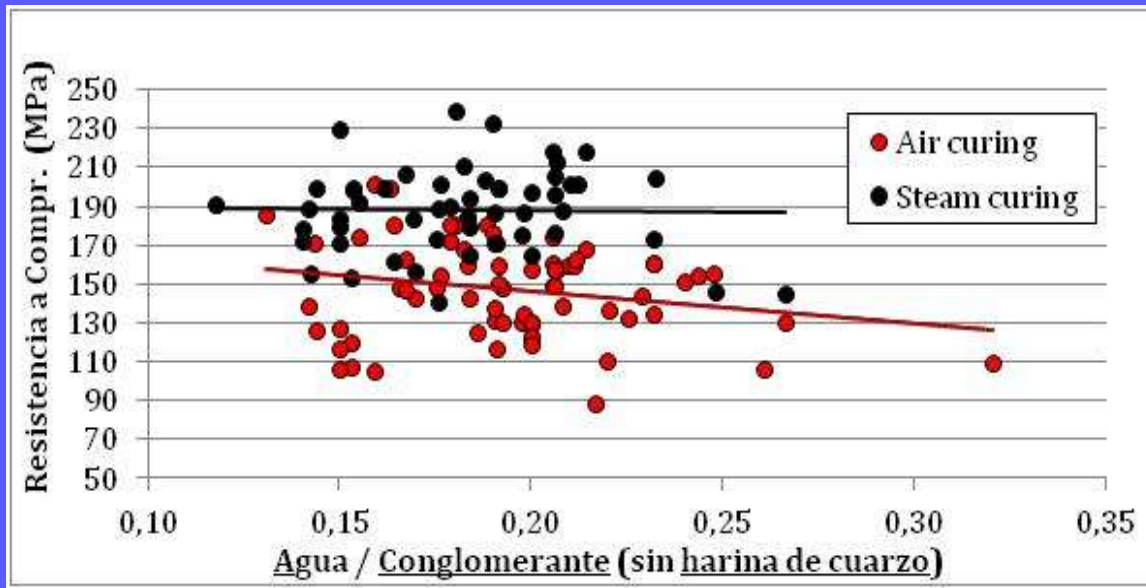




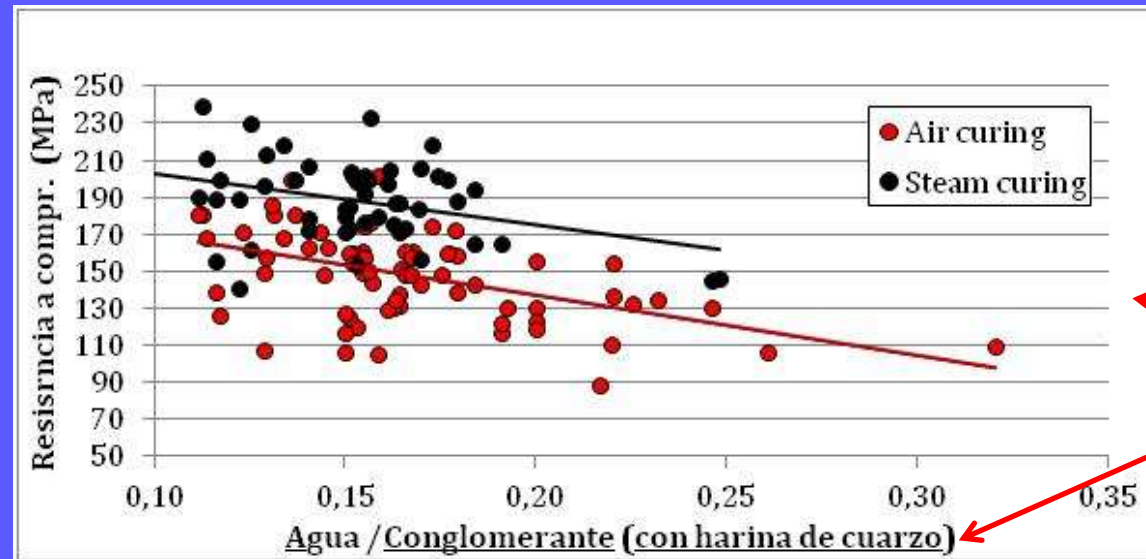
Diseño de dosificaciones



Bibliografía - Resistencia

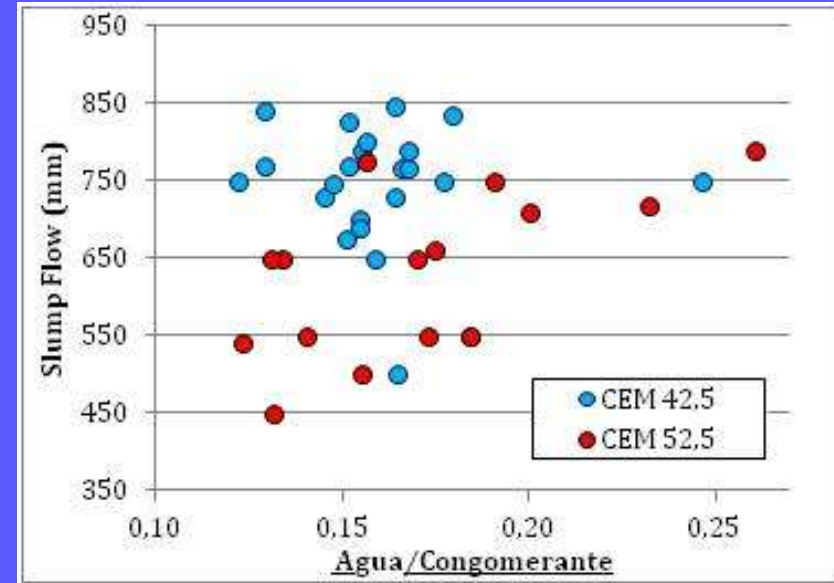
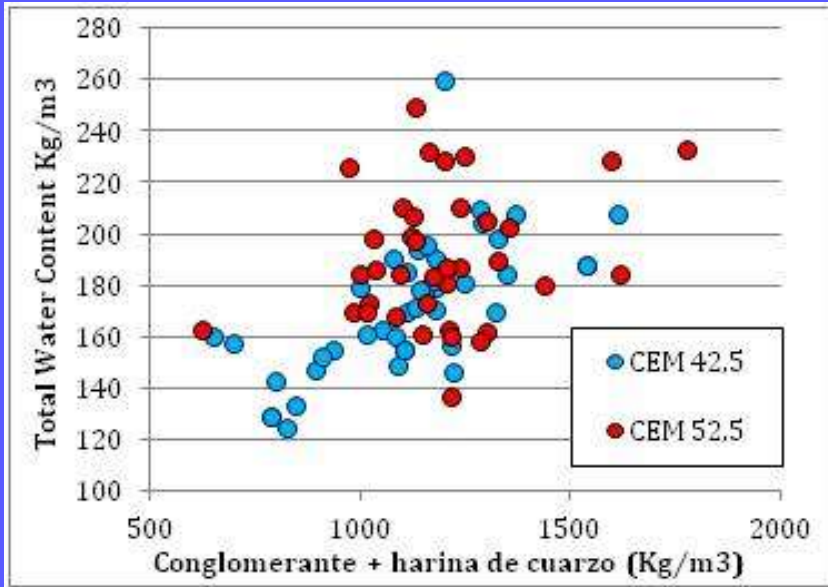


Difícil superar
200 Mpa
Sin Curado al Vapor



Mejor

Compatibilidad de Materiales



Garantizar:

- Trabajabilidad / expulsión de aire
- Reducir Calor de hidratación
 - Cemento 42,5
 - Resistencia a sulfatos
- Con el menor contenido en agua

Distribuciones Granulométricas

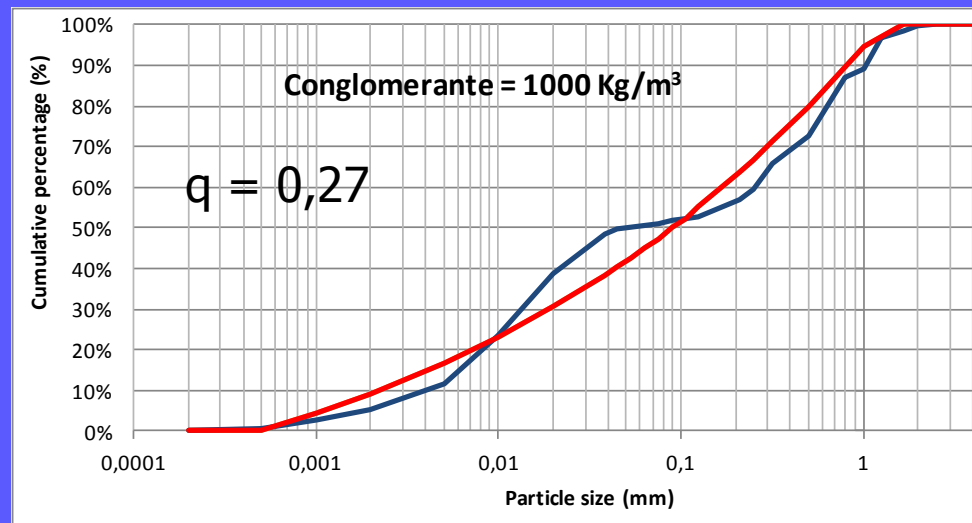
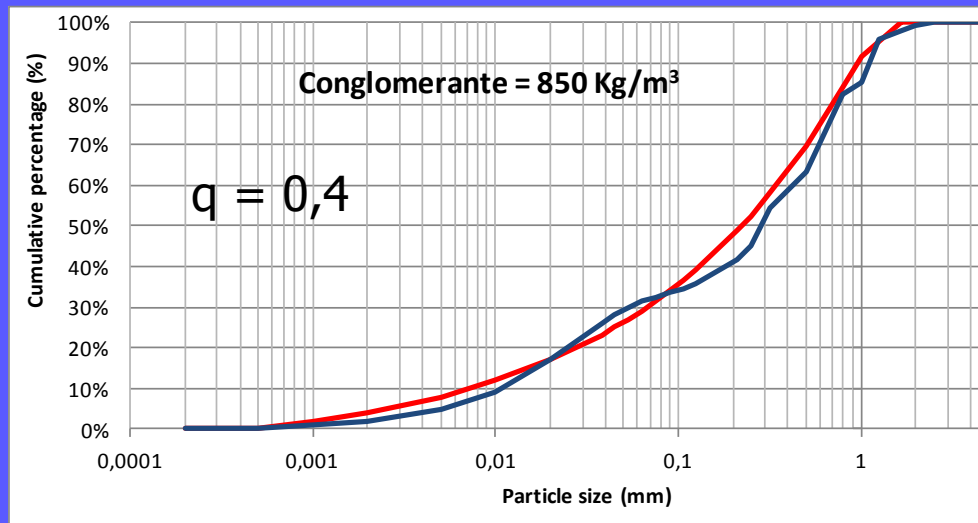


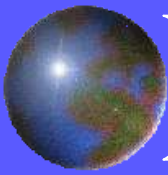
De Calidad - Sílice
Máxima Compacidad
 ¿Curvas Discontinuas?

$$\frac{CPFT}{100\%} = \frac{d^q}{D_{Max}^q}$$

Con CPFT = % que pasa por el tamiz d

Fuller: $q = 0,5$
 Sólo áridos
 Recom: $q = 0,2 - 0,37$
Todos los sólidos





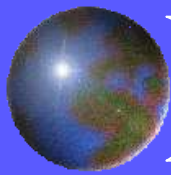
Caracterización – Estado Fresco

Como en SCC

Viscoso -- Depende de la dosificación

- Ecurrimiento
- Viscosímetro
 - Tensión de corte
 - Viscosidad
- Otros (Caja L ...); Segregación -- ¿?



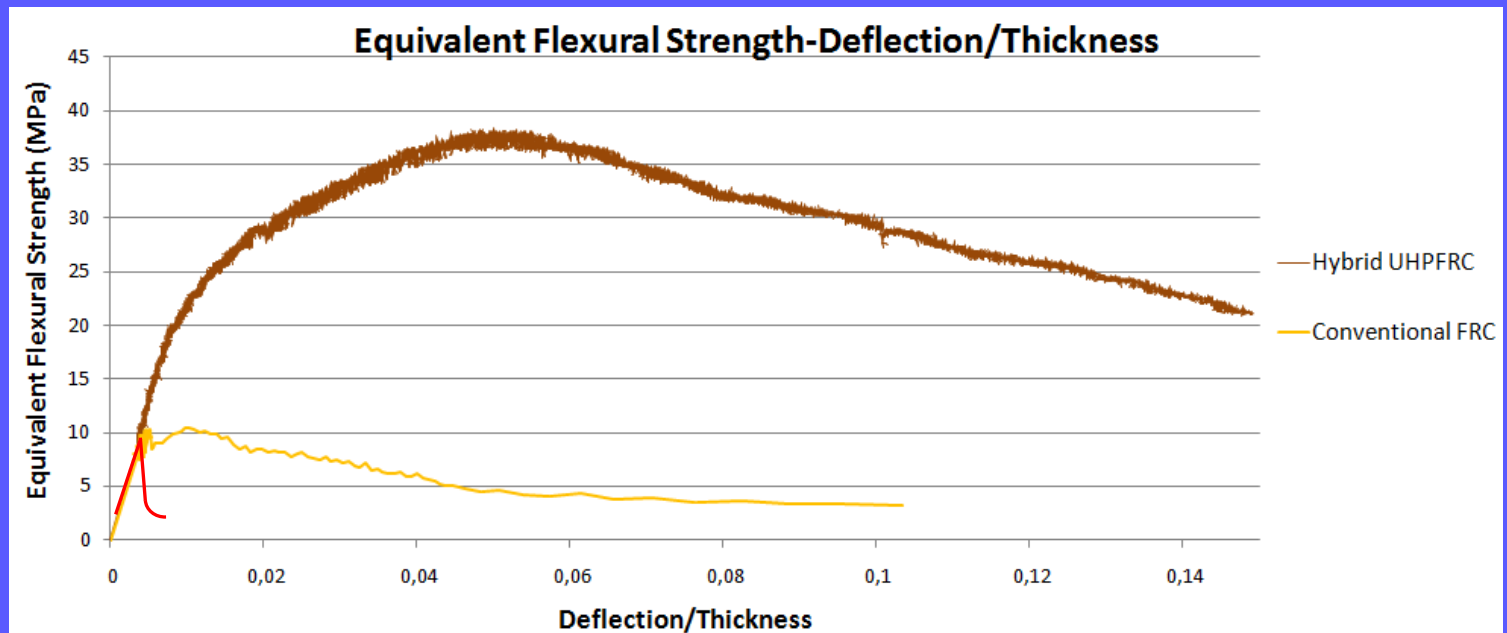


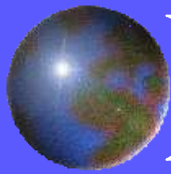
Caracterización – Estado endurecido

Ensayo de flexión

Dimensiones:

- Según pieza a analizar
- Orientación – afecta ¿? **SI**
- ¿Representativa?



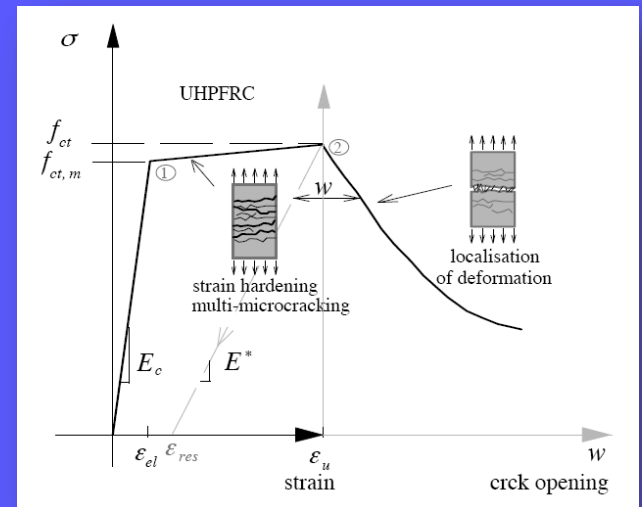
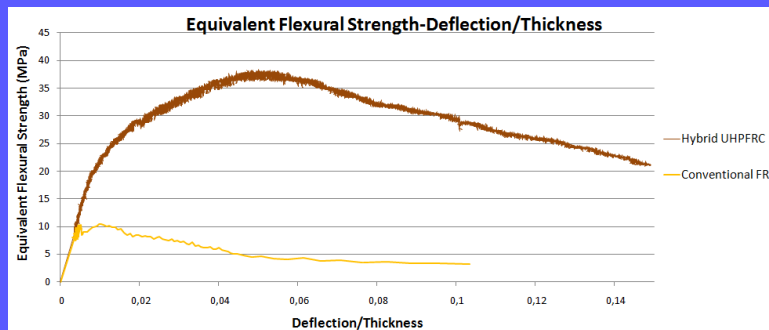


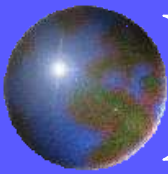
Caracterización – Estado endurecido

Resistencia equivalente a flexión >> Resistencia a tracción

Obtención de la ley constitutiva a tracción
Ley Trilineal
Deformación plana

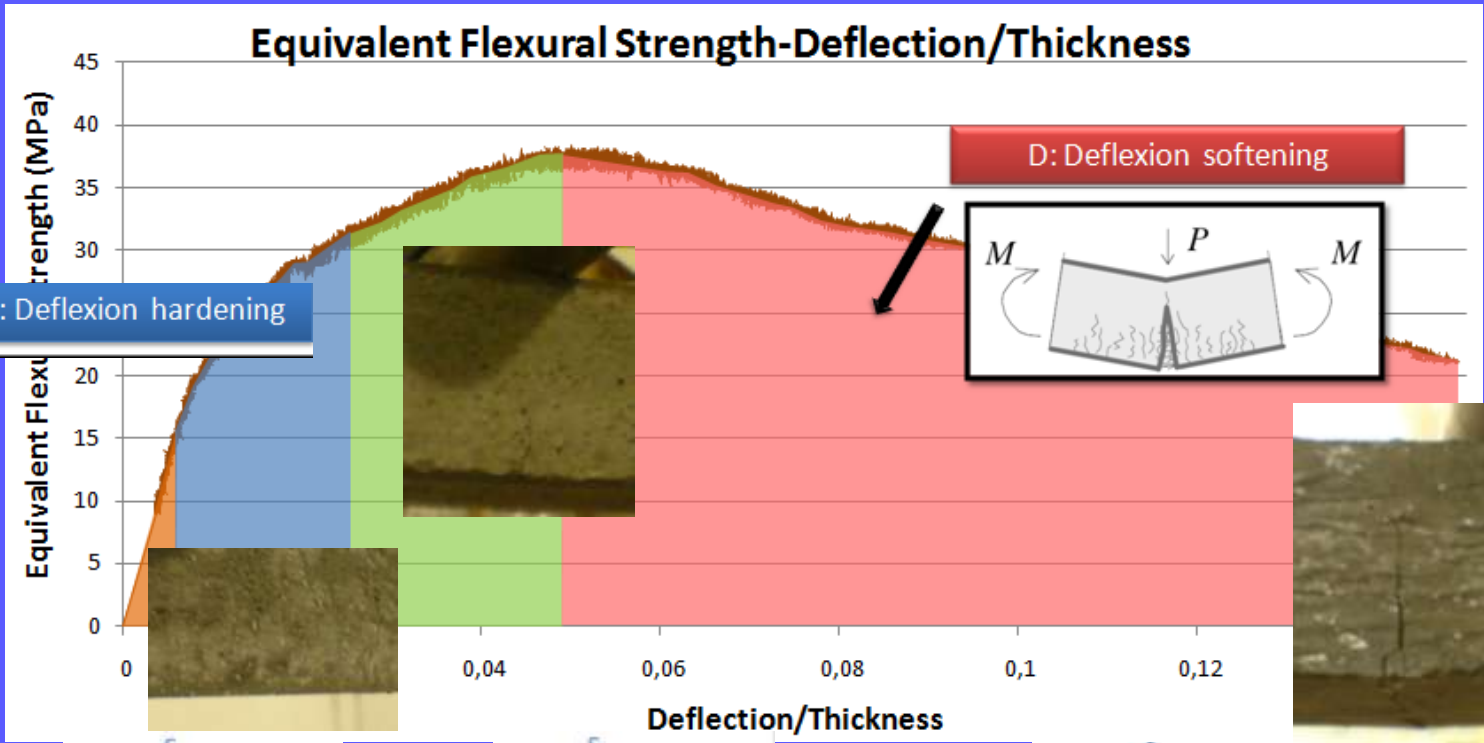
Análisis Inverso



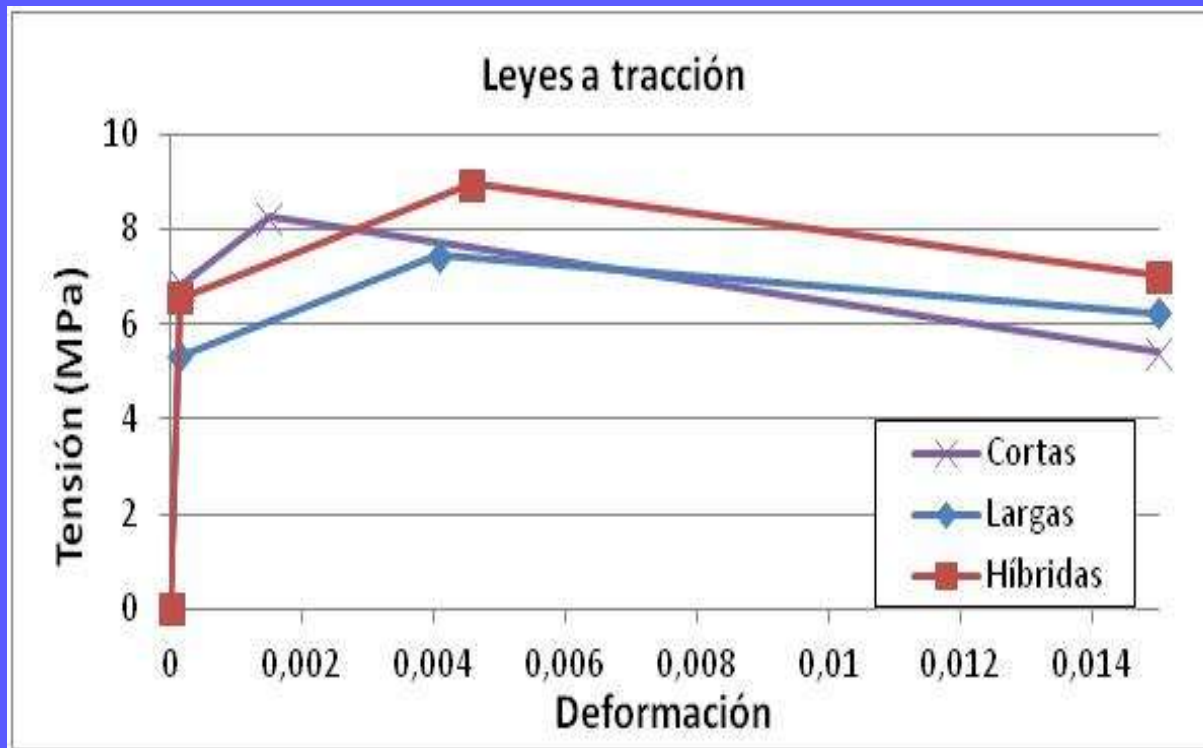


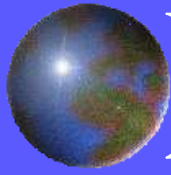
IBRACON
40 ANOS
ferrando o concreto no BRASIL
CONGRESSO BRASILEIRO DO CONCRETO
54
Maceió - Alagoas

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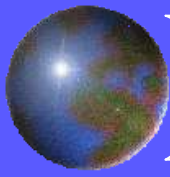


Efecto del tipo de fibra





Development of three levels of UHPFRC-VHPFRC



Develop three levels of UHPFRC-VHPFRC

Kg Cement / m³: **Basic**→700, **Medium**→850, **High**→1000

High level: $D_{\max}=2$ mm,
high strength fibers Dramix RC-80/30-BP,
EIRICH intensive mixer, A&A theory.

Medium and basic level:

- Crushed coarse limestone aggregate 4-7 mm
- Normal tensile strength steel fibers Dramix RC-65/35-BN
- Tilting mixer
- Own compacity theory - Compacity Ternary Diagram, CDT
- Cements: I 42.5 R/SR or I 52.5 R/SR.
- National active additions
- No Termal curing
- Hybrid** concretes:
 - 1% of Dramix =L 13/0.16 and 1% of longer fiber.
- Slump-flow ≈700 mm.

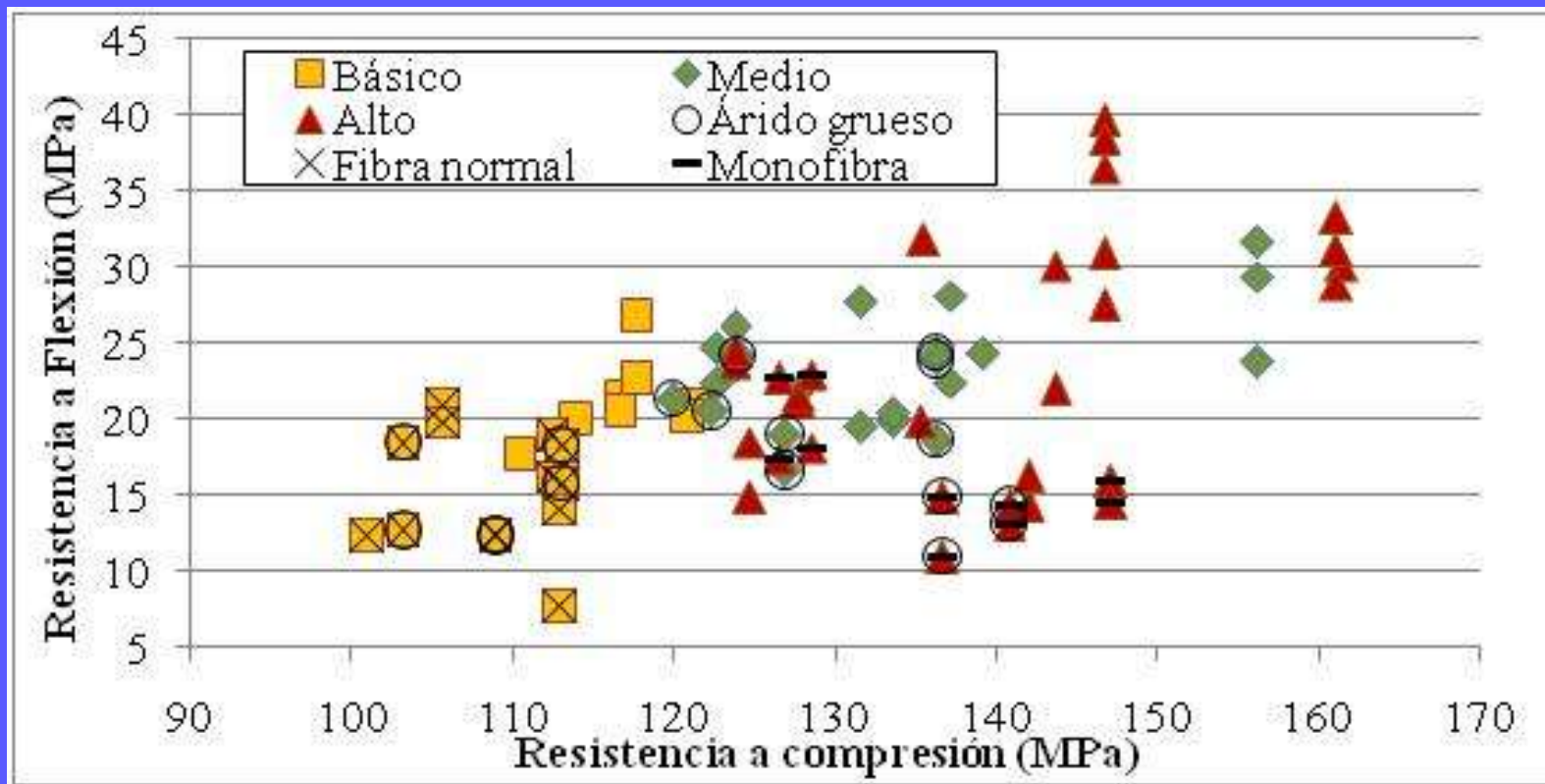


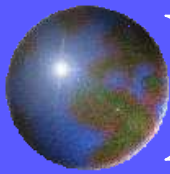
dosificaciones tipo desarrolladas



Dosificación	Nivel básico	Nivel medio	Nivel alto
Tipo de cemento	42.5 R/SR	42.5 R/SR	42.5 R/SR
Contenido de cemento (Kg/m ³)	635	850	1000
Tipo de adición activa	HdS Ferroat	FC3R	FC3R
Contenido de adición activa (% s.p.c.)	10%	10%	15%
Relación Agua/Conglomerante	0.26	0.21	0.175
Aditivo PCE (% s.p.conglom.)	4.5% tipo C	4.5% tipo C	3% tipo B
Árido grueso calizo 4-7 mm (Kg/m ³)	600	0	0
Dmax. Arena (mm)	1.3	1.3	1.6
Tipo de fibras largas	RC-65/35-BN	RC-80/30-BP	RC-80/30-BP
Contenido de fibras (cortas+largas) (%)	0.75% + 0.75%	1% + 1%	1% + 1%
Paste Volume Fraction (%)	42.5%	52.7%	59%

Propiedades	Nivel básico	Nivel medio	Nivel alto
T50 (s.)	30	17	7.5
Escurrimiento (mm)	588	763	800
Resistencia compresión a 24 h (MPa)	62.4	67.2	71.9
Resistencia compresión a 7 días (MPa)	101.5	120.6	139.2
Resistencia compresión a 28 días (MPa)	127	137.2	161.2
Resistencia a flexión lineal equiv. (MPa)	17.8	25.3	31.1
Energía acum. hasta 3 mm (MPa*mm)	47.2	66	80.1





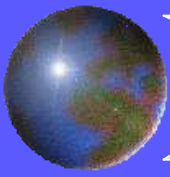
Influencia del tipo de amasadora



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Nº	Nombre de la amasadora	Volumen máximo (litros)	Volumen amasado (litros)	Potencia Total (kW)	Tiempo de amasando (min)	Kg de cem - Agua/Binder	Potencia unitaria (W/litro)	Resistencia obtenida
1	Ensayo de morteros	1	1	0.37	12	A - 980 - 0.20	370	165.5
2	De obra basculante	30	20	0.243	26	B - 850 - 0.23	12	131.6
3	Pemat Zyclos ZK50HE	50	25	2.25	18	A - 980 - 0.20	90	148.6
4	Betonmass* ST150 CD	110	100	4.05	15	A - 960 - 0.22	41	113.8
5	intensiva EIRICH R-08W	50	50	11	13	B - 850 - 0.21 A 1000 - 0.17	220	141.4 160.2
6	Fejmert FP-1-RM	1000	500	37	15	A - 980 - 0.20	74	150.0

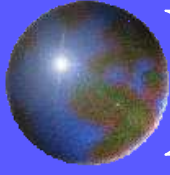




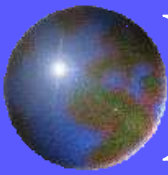
Algunas consideraciones tecnológicas



- Cuidar velocidad y orden de llenado -- flujo
 - **juntas frías**
 - **Orientación** de las fibras
- Exige calidad en las juntas de encofrado – Evitar fibras vistas



Aplicaciones Desarrolladas



Aplicaciones - Introducción



■ UHPFRC

- Alta Resistencia
- Autocompactable
- Fibras



- Durabilidad
- Esbeltez
- Eliminación de armadura secundaria
- Uniones / Pefabricación

Limitación



COSTE



**DISEÑO
OPTIMIZADO**

Ideas de precio

COSTE



Básico	600	€ / m ³
Medio	750	€ / m ³
Alto	900	€ / m ³
Productos comerciales	2000	€ / m ³

(2,5 Reales / €)

Causas:

1.- Fibras

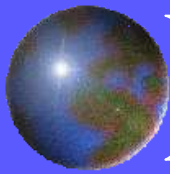
2.- Cemento y Adiciones Activas

3.- Otros

Solución	Coste m ³	Vol. usado	Tiempo montaje	Coste transporte	Vida útil
H. convencional	1	1	1	1	1
UHPFRC	8-10	0.2-0.5	0.2-0.5	0.3	4

Para ser competitivo – reducir el peso a ¼
(Peso similar a estructura metálica)



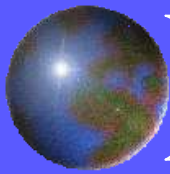


Diseño optimizado de la mezcla



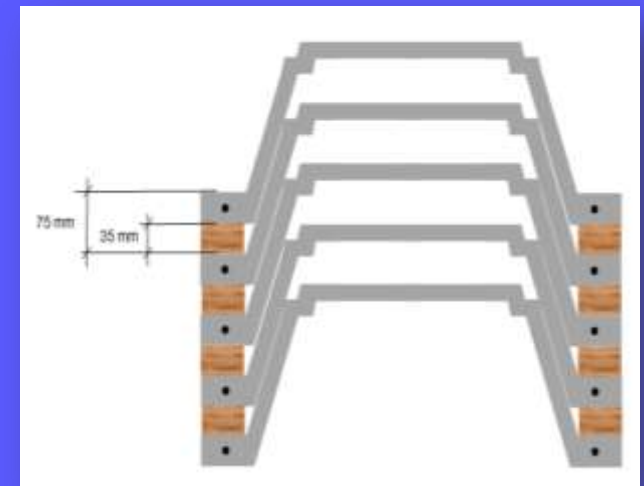
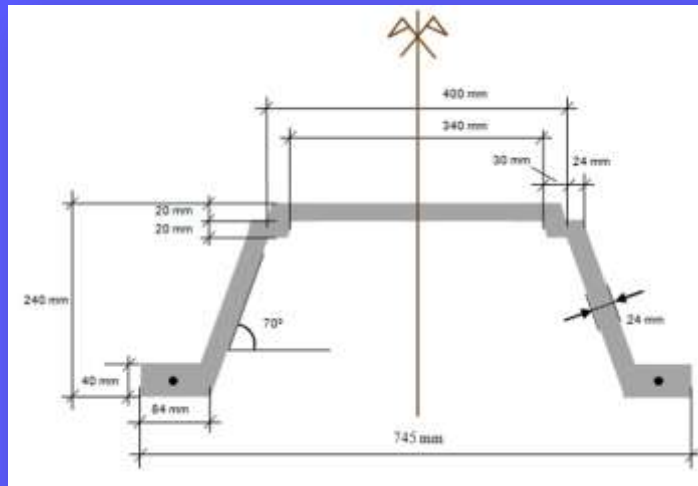
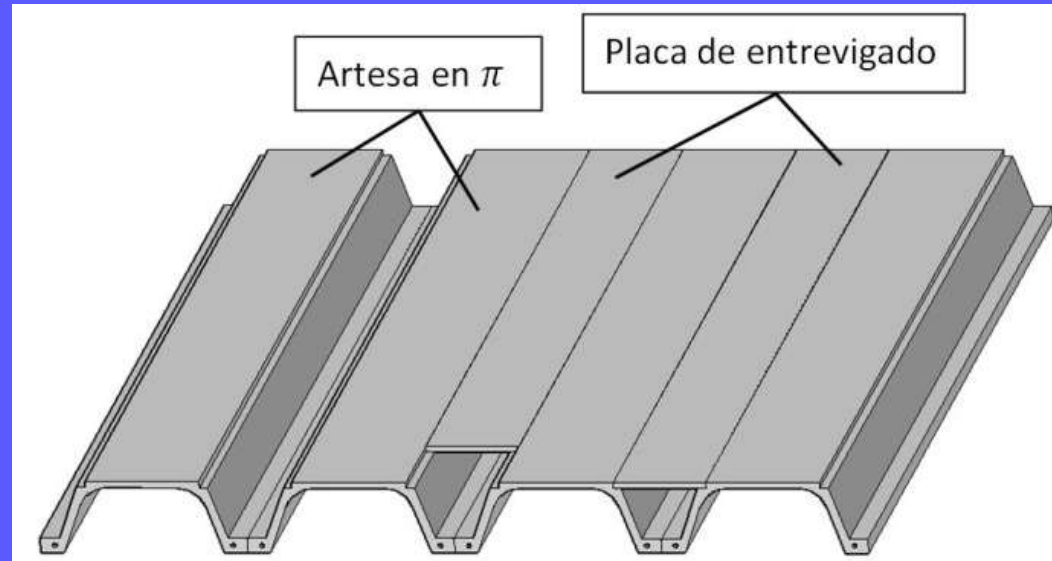
Aplicación	Tipo de fibras	Tamaño árido
Elementos finos con poco armado o inexistente (placas delgadas, elementos de fachada...)	Híbrido	Fino
Aplicaciones sometidas fundamentalmente a tracción directa o a cortante elevado (tirantes de UHPFRC)	Híbrido	Fino
Aplicaciones con dificultades de vertido o alta densidad de armado (tuberías prefabricadas)	Fibra corta	Fino
Elementos gruesos sometidos a flexo-compresión (pilares)	Fibra corta	Grueso
Elementos pretensados espesores considerables (vigas pretensadas para puentes)	Fibra corta	Grueso / Fino

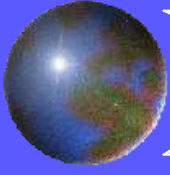
Definir exigencias de resistencia a compresión y comportamiento a tracción según necesidades



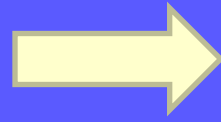
Diseño optimizado Estructural 1

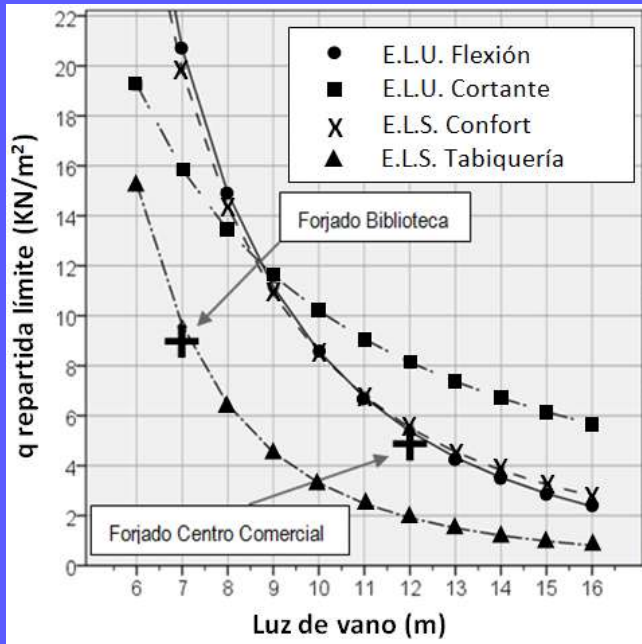
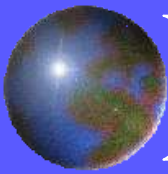
Sistema de forjado



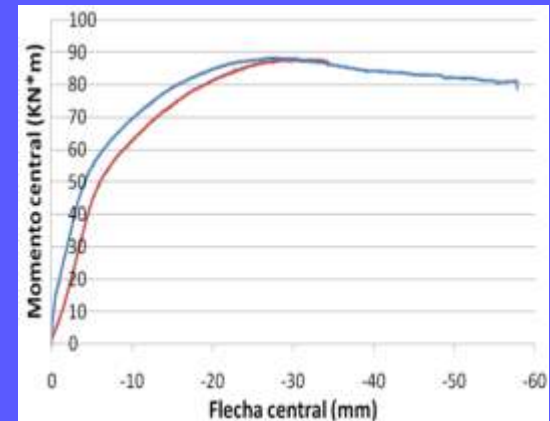


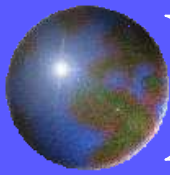
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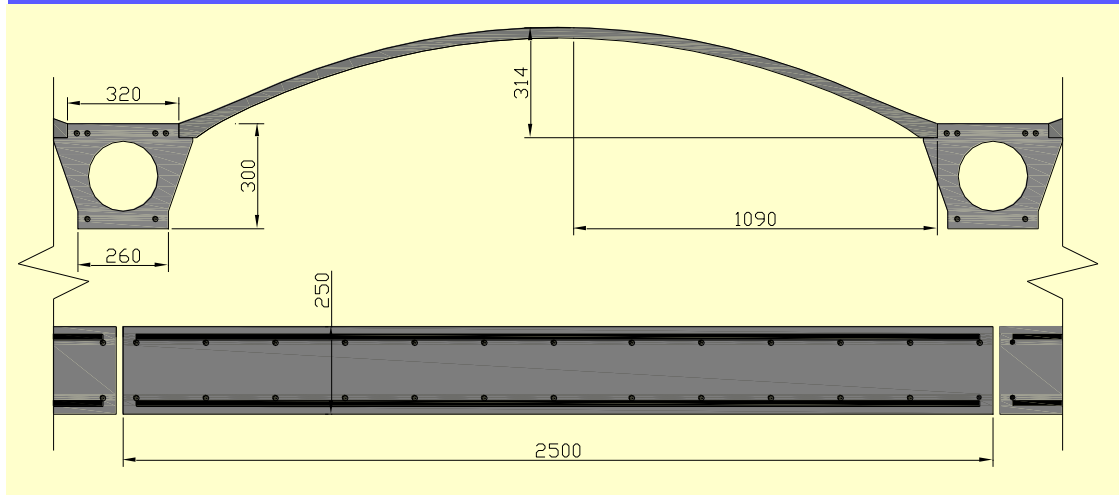
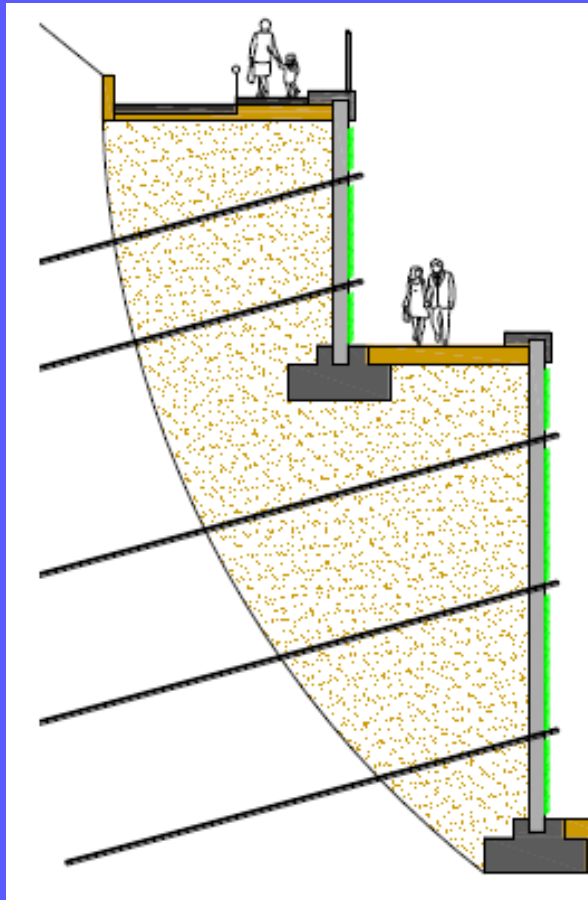


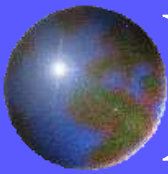
Carga repartida límite q con cordones de 7 alambres $\Phi 13$ mm.





Diseño optimizado Estructural 2

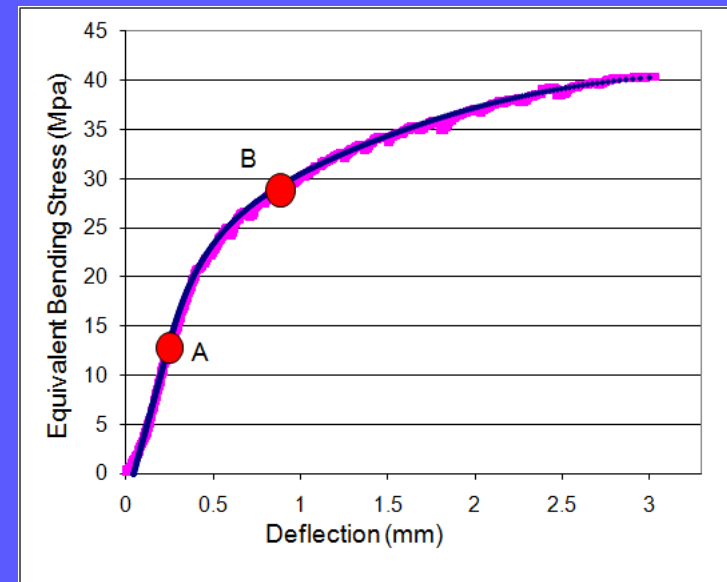
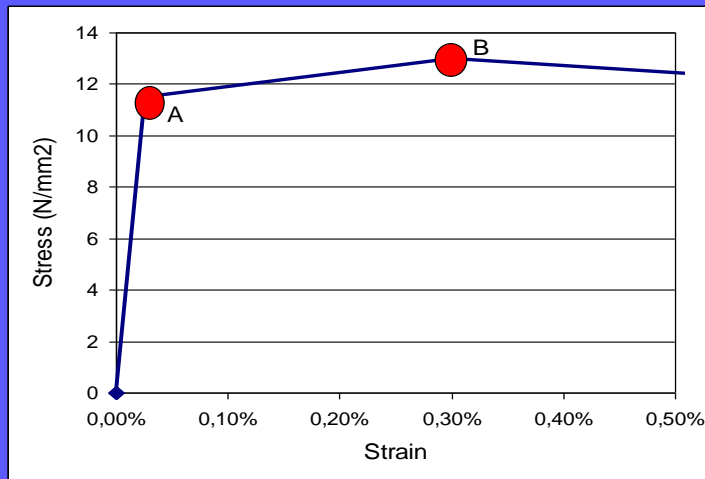




Ensayos

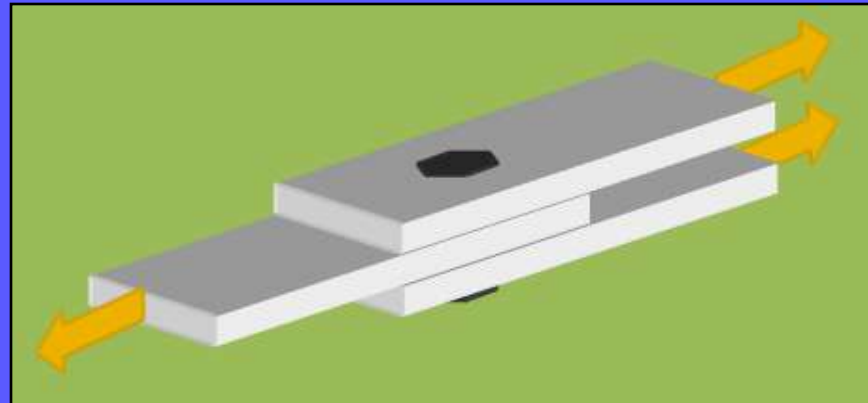


	Valor	CV %	Probetas
fcm	150 Mpa	4	100x100x100
fctm	11 Mpa	5	100x100x500
fctu	13,5 Mpa	11	100x100x500
Escurremiento	760 cm	-	-



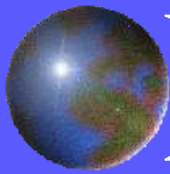
Diseño Estructural 3

Bolted Joints for UHPFRC Precast Prestressed Elements

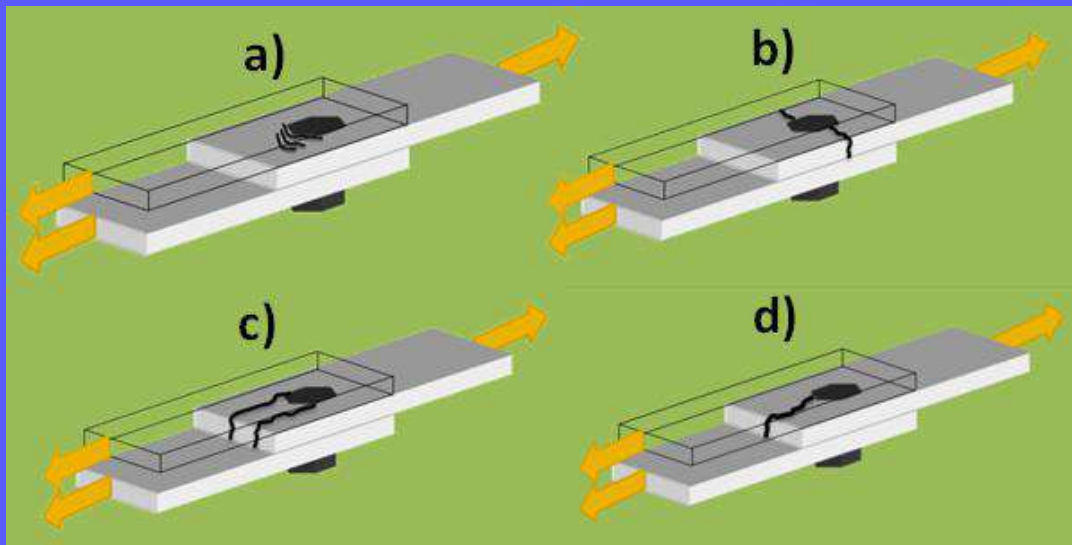
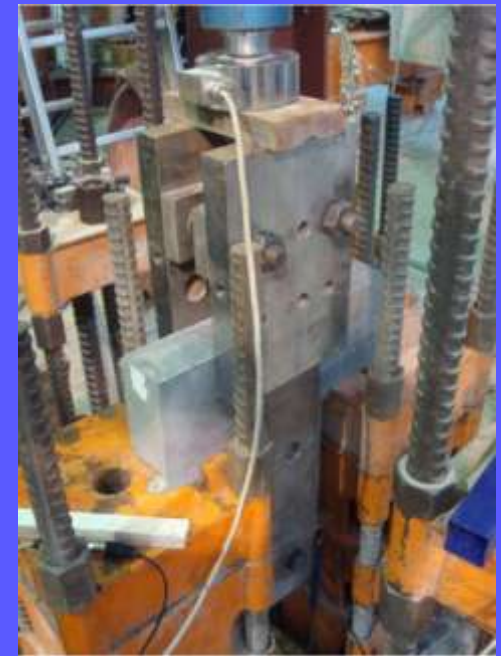


Advantages

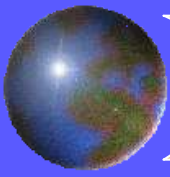
- Precast - Fast system for industrial structures, trusses
- Easy transport and assembling



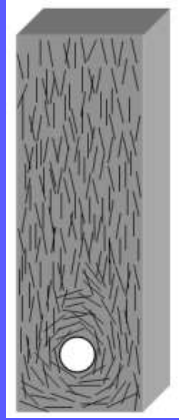
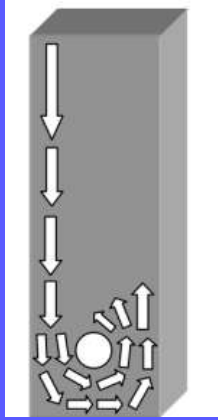
Test Methodologie



- a) Bearing failure
- b) Net tension failure
- c) Shear out failure
- d) Cleavage failure



Results

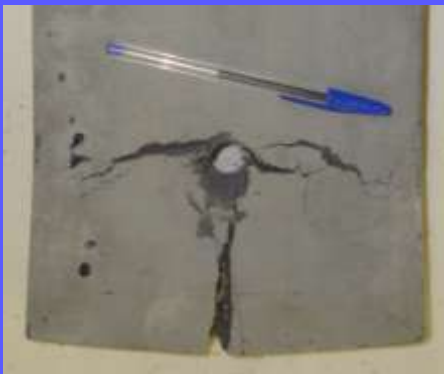


Effect of fibers orientation

Failure Mode depends on:

- Longitudinal reinforcement
- Transversal reinforcement
- Cover

Direct tension Failure is possible



Proyecto Gar-Field

Garden **Art-Furniture** **E**lements **D**evelopment

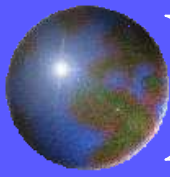


Juan Ángel López
Esteban Camacho
Coordinado por Pedro Serna



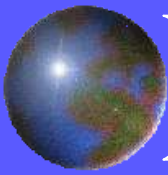
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Aspectos

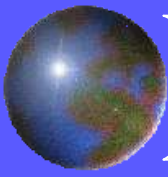




Joyería – Menis Arquitecto



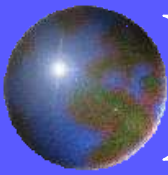
<http://www.menis.es/index.php/concrete-ring/>



Pasarela Barranco de las Ovejas - Alicante



Pasarela Barranco de las Ovejas – Alicante – Um reto



Pasarela Barranco de las Ovejas - Alicante

Objectives

- ➊ Design a **competitive** UHPFRC footbridge as an alternative to a steel one
 - Take full advantage of the UHPFRC mechanical properties
 - Guarantee its production in a conventional precast factory
- ➋ Assess the footbridge safety
 - AFGC-SETRA Recommendations for UHPC
 - Spanish Concrete Code (EHE-08)
 - Perform a representative test of the design
- ➌ Study of the most important structural problems
 - Buckling
 - Construction joints
 - SLS in elements subjected to pure tension

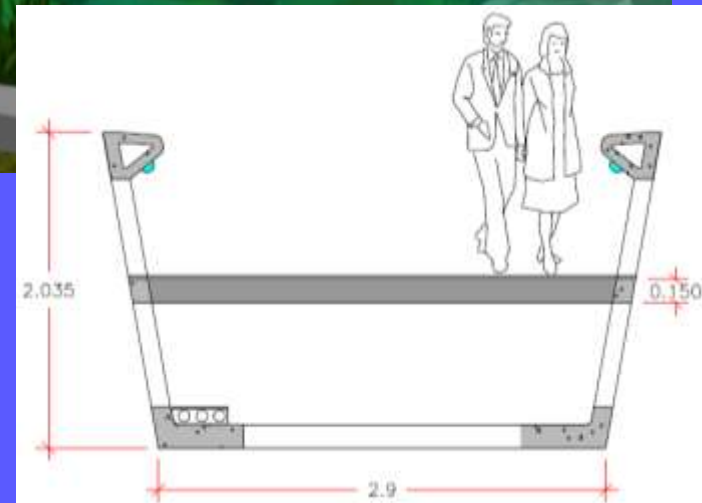
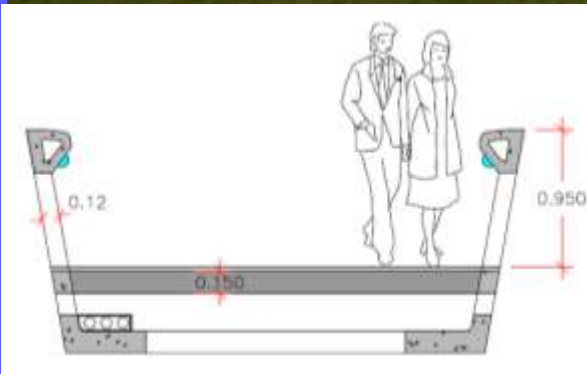
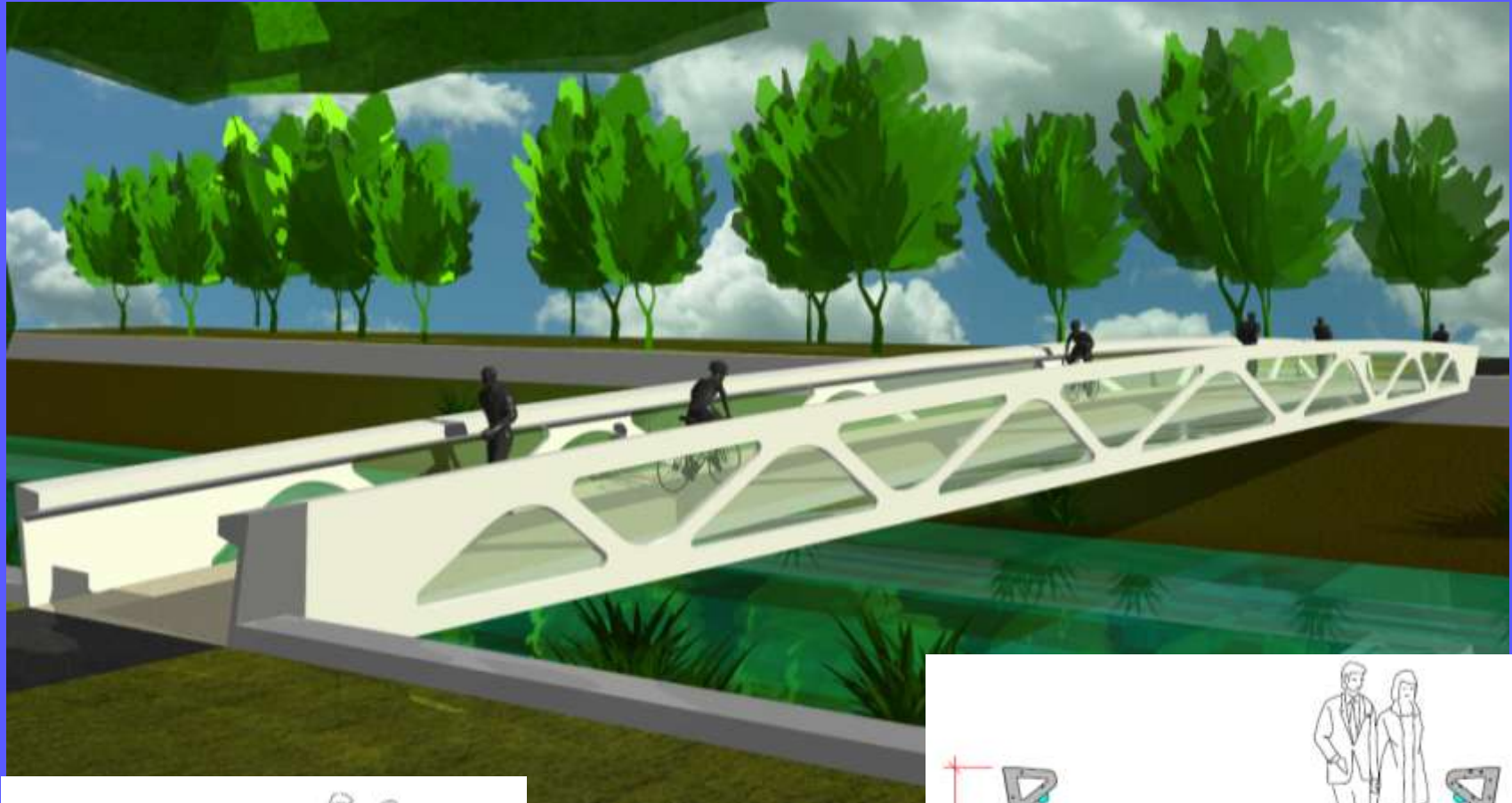


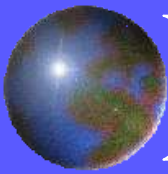


Design

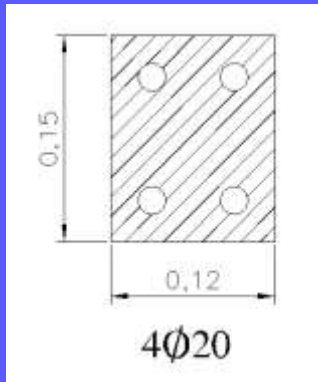
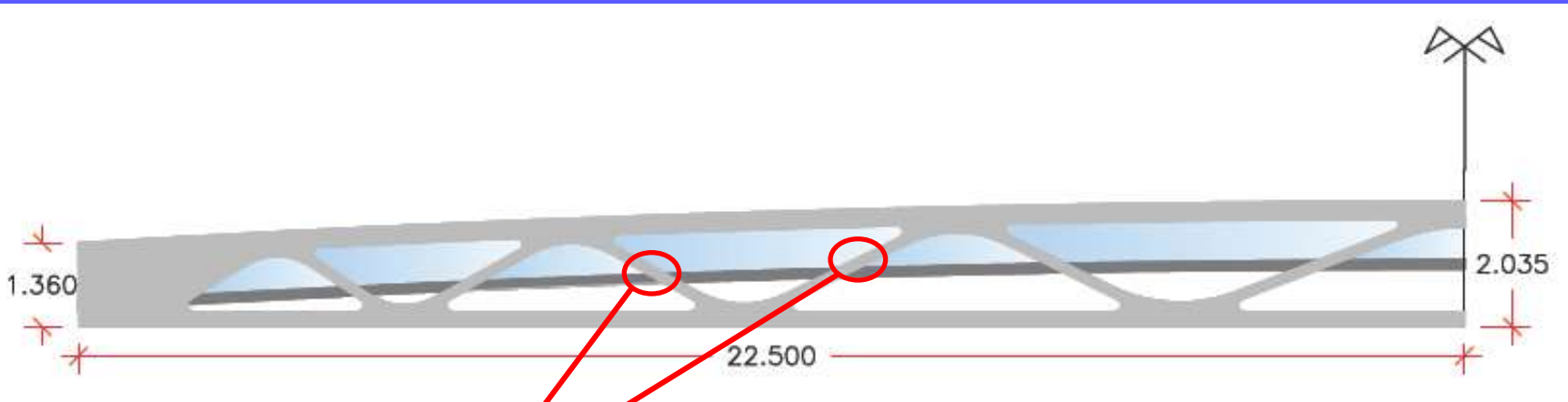


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08 a 10/10 de 2017 - Maceió/AL

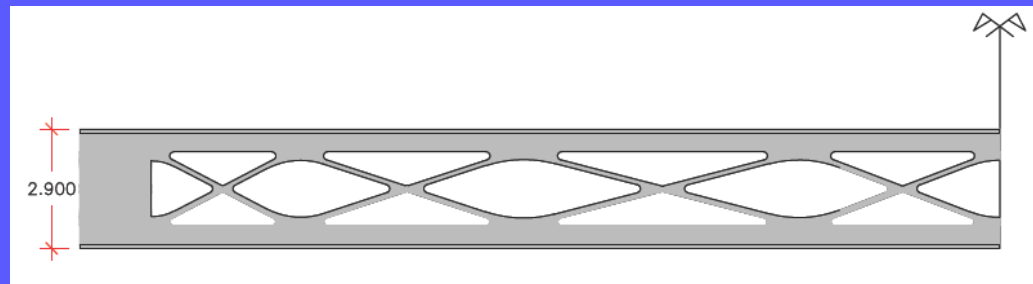


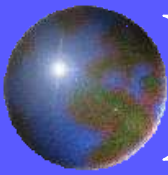


Design



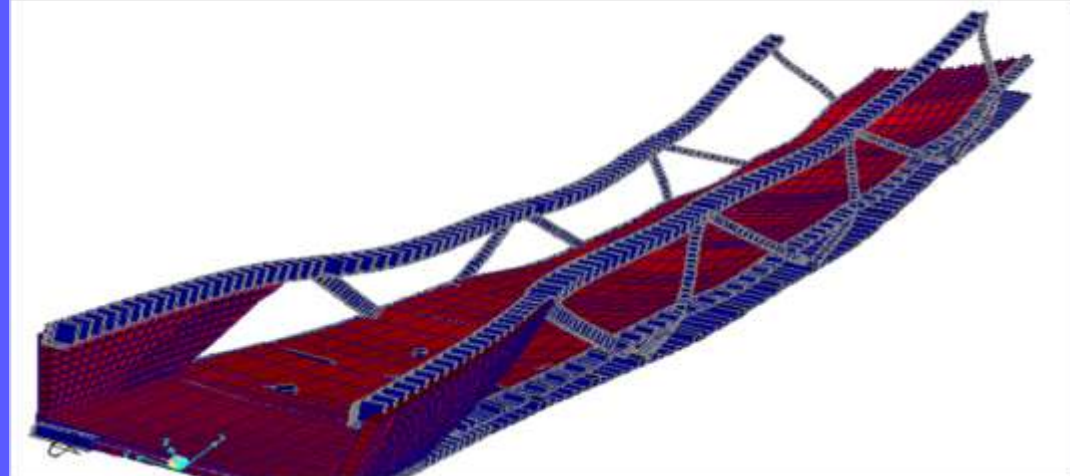
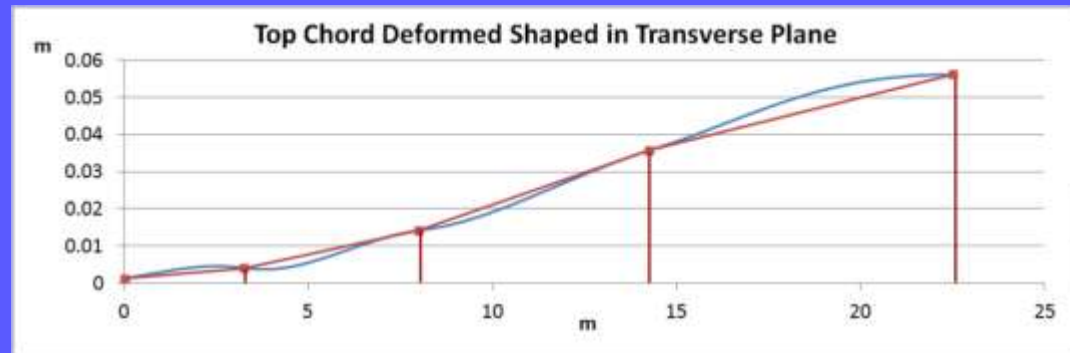
- Both compressed and tensile diagonals are heavily reinforced
 - Transverse bending
 - Prevent top chord buckling
 - Structural ductility

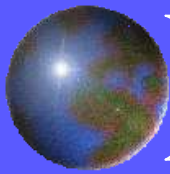




Buckling

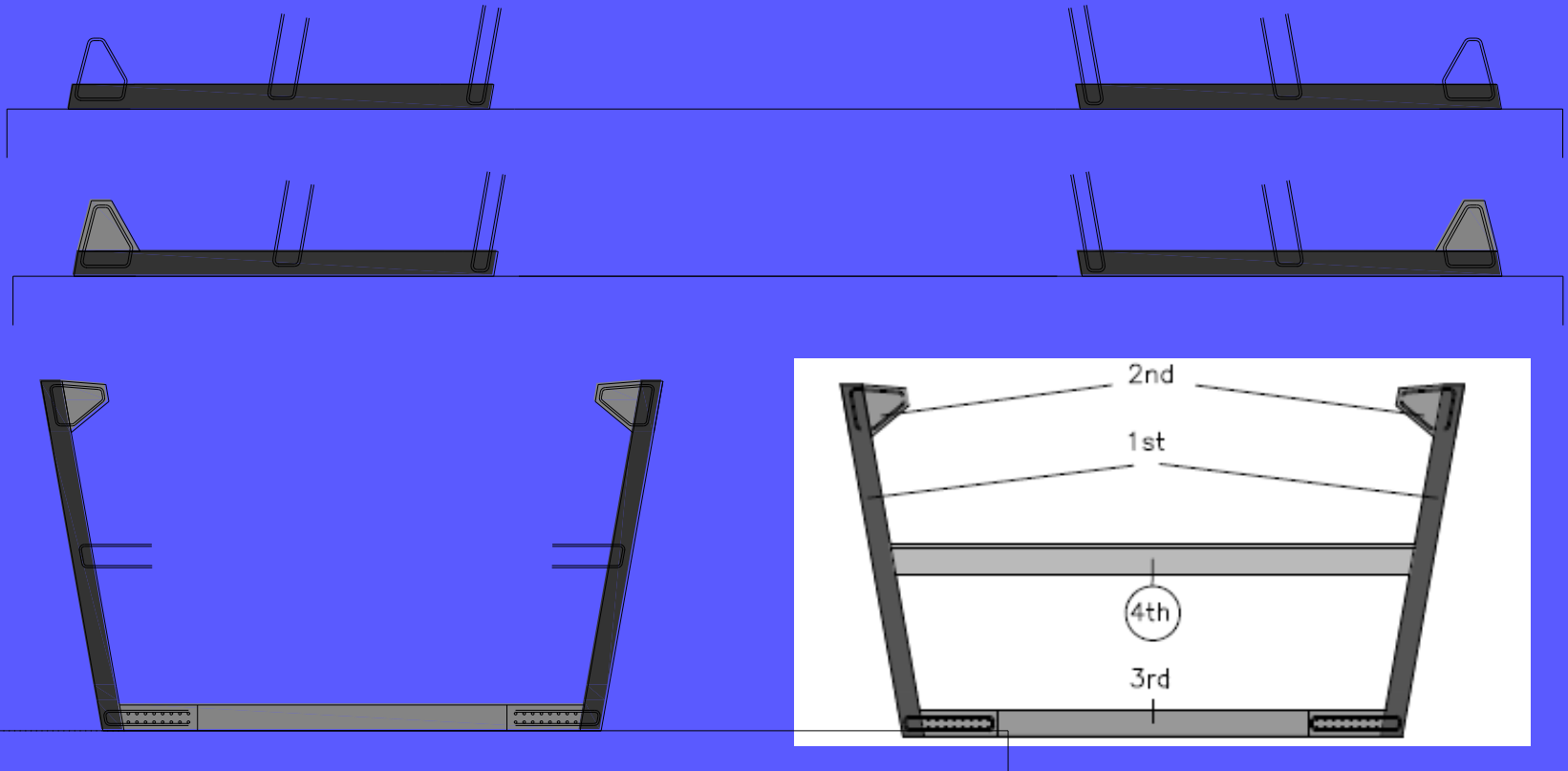
- Non-linear analysis for the worst load combination
 - Fast convergence process
 - Small lateral displacements
 - Second order section-forces checked

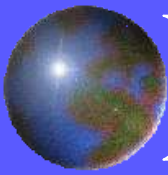




Casting process

- Precast the whole footbridge at the factory
- In 4th steps
- Construction joints



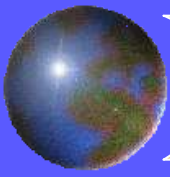


Truss Test



- ❑ Trusses are usually designed in steel → Why a truss?
 - UHPFRC needs lightweight designs to be competitive
 - A truss makes a light design possible
 - Elements are mainly subjected to axial forces
 - High compressive strength





Truss Test

No visible cracking until
reinforcement yielding stress



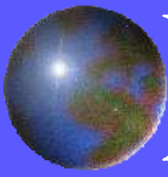
$$\epsilon = 2 \text{ ‰}$$



AKNOWLEDGEMENTS



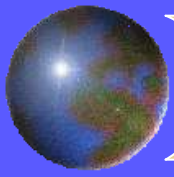
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UHPFRC: De los componentes a la estructura

Serna Ros, Pedro;
López Martínez Juan Ángel;
Camacho Torregrosa, Esteban





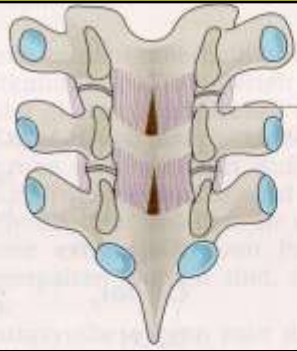
Why precast structures ??

..it is a nice game..

With FRC more
robustness, less
maintenance,
better structures..



Fibres-learning from nature



Ligamenta flava

Zellkern des Fibrozyten

No life without fibres!!



elastische Fasern

elastische Fasern

Fibrozyt

With fibres the life is better!!

Thank you!!

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