Reactive Powder Concrete
A New Type of Concrete

RPC

or

UHPFRC

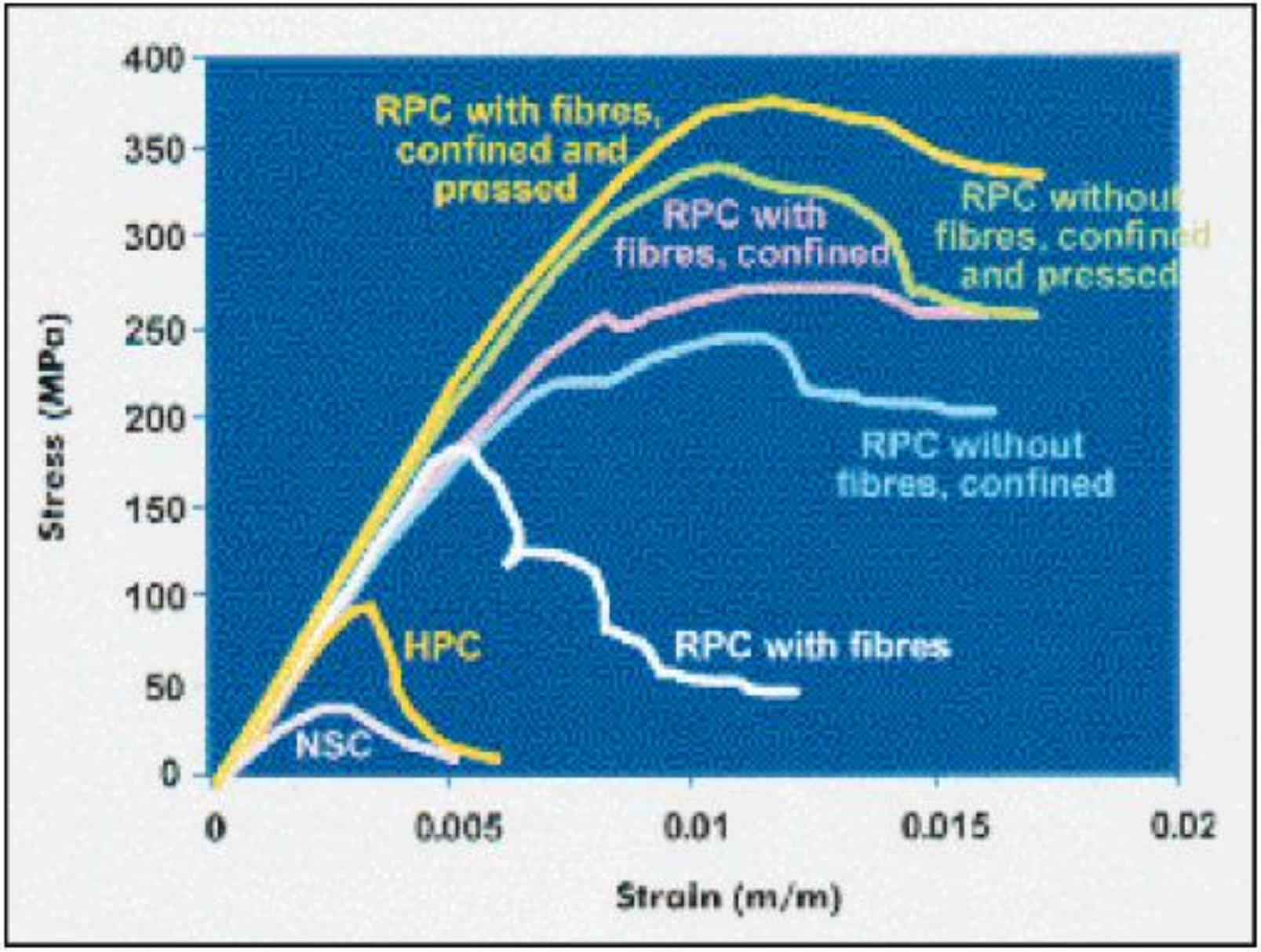
Reactive Powder Concrete

- What is it?
- What does it do?
- What is its applicability?
- Why should we care?
- Where is it headed?

Introduction:

- Reactive-powder concrete (RPC) was first patented by a French construction company in 1994. It is characterized by high strength and very low porosity, which is obtained by optimized particle packing and low water content.

- The compressive strength of reactive-powder concrete is typically around 200 MPa (29,000 psi), but can be produced with compressive strengths up to 800 Mpa (118,000 psi)



مقایسه منحنی‌های تنش-کرنش برای انواع بتن‌ها

The properties of RPC are achieved by:

1. Eliminating the coarse aggregates;

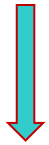
using very fine powders such as:

Sand, Crushed quartz, Silica fume

particle sizes between 0.02 and 600 μm

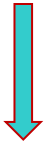
The properties of RPC are achieved by:

2. Optimizing the grain size distribution



densify the mixture

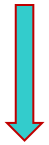
3. Post-set heat-treatment to



improve the microstructure

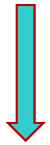
The properties of RPC are achieved by:

4. Addition of steel fibers (about 2% by volume)



high ductility and energy absorption

5. Use of superplasticizers



decrease the water to cement ratio-usually to less than 0.2—while improving the rheology of the paste

The properties of RPC:

- Low permeability
- Limited shrinkage
- High corrosion and abrasion resistance
- High durability
- Reacting all of the powders during or after the hydration reaction at ambient temperature

The properties of RPC:

- RPC can also be considered as a mortar with:

- a very high paste content
- high silica fume content
- low water/cement ratio

Typical Mechanical Properties of RPC Compared to an 80-MPa Concrete

Property	Unit	80 MPa	RPC
Compressive strength	MPa (psi)	80 (11,600)	200 (29,000)
Flexural strength	MPa (psi)	7 (1000)	40 (5800)
Tensile strength	MPa (psi)		8 (1160)
Modulus of Elasticity	GPa (psi)	40 (5.8×10^6)	60 (8.7×10^6)

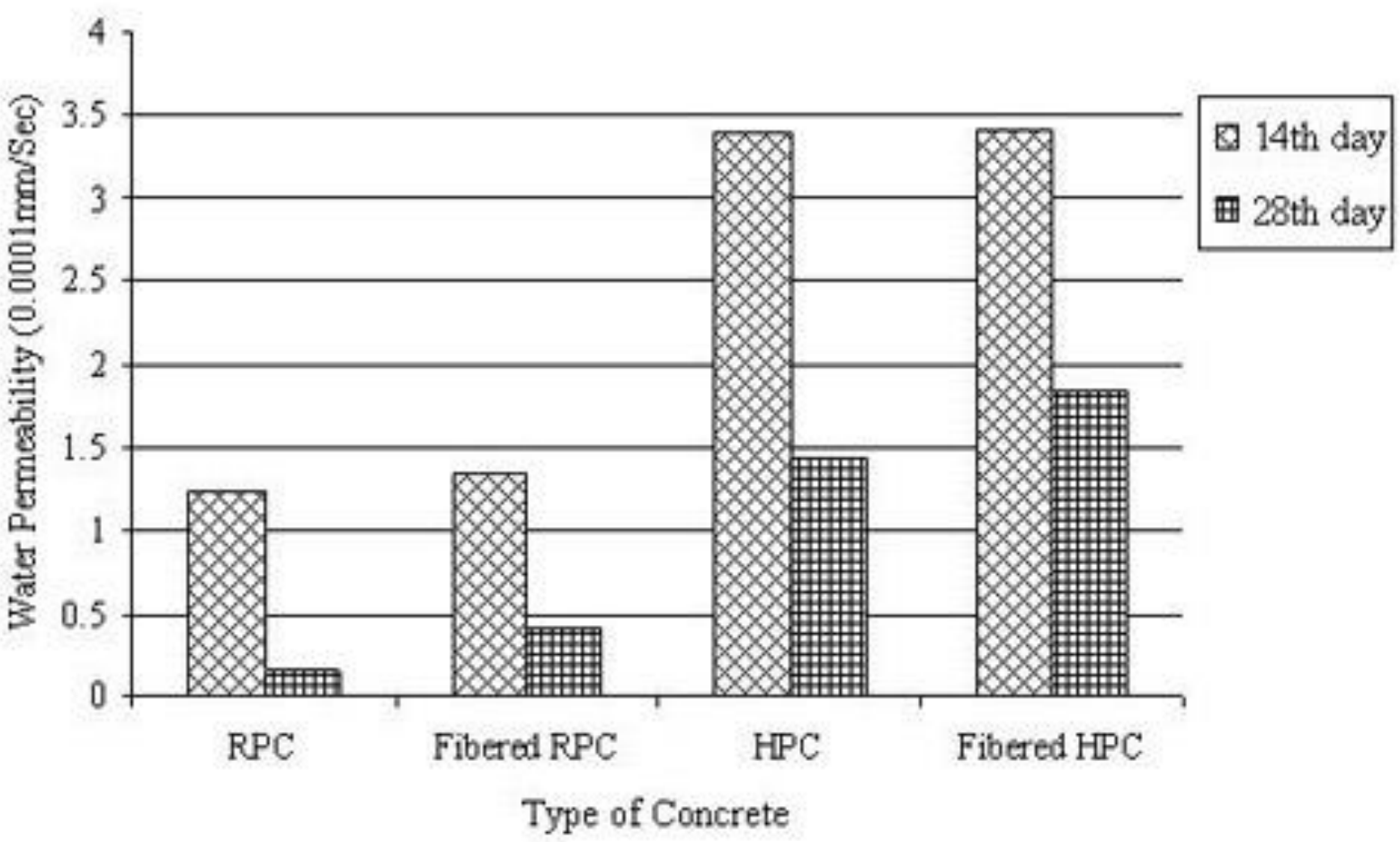


Fig. 3: Surface Water Permeability of RPC and HPC

RPC Composition:

1. Portland cement (type II and type V)

- Cements with low C_3A content give better results
- Cements with a high Blaine fineness are not satisfactory, due to their high water demand.
- Cement should have a moderate fineness and a C_3A content significantly lower than 8% to reduce the demand for water, which influences compressive strength.

RPC Composition:

2. Fine quartz sand (150-600μm)

- highly angular sand
- natural quarry sand, where the grains are more spherical

- Advantages of quartz sand
  - Very hard material
  - Excellent paste/aggregate interfaces

RPC Composition:

3. Crushed quartz

Maximum reactivity during heat-treating is obtained for a mean particle size of between 5 and 25 μm (The mean particle size = 10 μm)(is the same granular class as the cement).

4. Silica fume

- The optimum amount: 25% of the cement by weight

RPC Composition:

5. Small size steel fibers

- Dimension of fibers :13 mm long, 0.2 mm diameter
- Strength:high-strength (tensile strength of 2600 MPa)
- Ratio of the fibers into the mix: between 1.5 and 3% by volume (The economic optimum ratio 2% by volume)
- Effect of fibers: improving the mechanical properties of the composite, particularly in terms of tensile strength and ductility.

RPC Composition:

6. High dosages of superplasticizer

   A superplasticizer based on polycarboxylate ether was found to be very effective.

7. Low ***w/c*** ratio : 0.16 to 0.27

   The optimum value: approximately 0.22

Mix Compositions (by weight)

mix design which is based on some published recommended compositions:

Materials	Cement	Silica fume	Silica sand	Silica powder	Superplasticizer	Water
Proportions	1	0.25	1.4	0.25	0.065	0.23

Advantages of RPC compared to the conventional concrete:

- Superior strengths with very high compressive strength of 200 MPa (approximately four times the strengths of conventional Concrete)
- RPC structures may weigh only one-third or one-half of the corresponding conventional concrete structures.
- Weight reduction is good in producing more slender transportation structures, reducing overall costs and increasing usable floor space in high-rise buildings.

Advantages of RPC:

- Superior durability which leads to long service life with reduced maintenance.
- Elimination of steel reinforcement bars reduces high labour costs and provides greater architectural freedom, allowing nearly limitless structural member shapes and forms for architects and designers.
- Reduction of thickness of concrete elements results in material and cost savings

Weakness of RPC:

- Cement content as high as 800–1000 kg/m^3 so it has negative effects on the environment.

RPC Mix:

In RPC, the number of ingredients is higher and the fineness of the particles is smaller compared to normal-strength concretes. Therefore, it is important that all particles, especially the very fine ones, are uniformly distributed. Because very fine particles tend to form chunks, and the minimal shear force for breaking these chunks can be reduced by keeping the particles dry, it is recommended to mix all dry particles first before adding the water and HRWR.

curing

- **Heat-curing**

- Heat-treating at 90°C substantially accelerates the pozzolanic reaction, while modifying the microstructure of the hydrates which have formed.

- High temperature heat-treating (at between 250 and 4OO°C), only applicable to fibered RPC.

curing

- **Application of pressure**

Compressive strength increases with density. An effective way of increasing density is to apply a pressure force to the fresh concrete.

Effects of application of pressure:

- Reduction of entraped air
- Excess water removal
- Improving the density

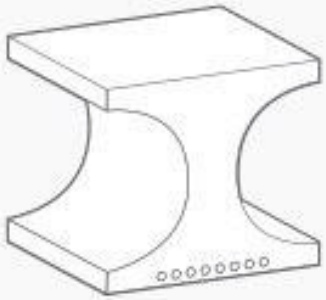
curing

Mechanical properties for the two types of RPC:

Pre-setting pressurization	None
Heat-treating	20 to 90°C
Compressive strength	170 to 230MPa
Flexural strength	30 to 60MPa
Young's modulus	50 to 60GPa

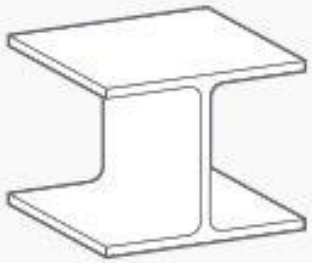
Pre-setting pressurization	5OMPa
Heat-treating	250 to 400°C
Compressive strength	
using quartz sand	490 to 680MPa
using steel aggregate	650 to 810MPa
Flexural strength	45 to 141MPa
Young's modulus	65 to 75GPa

RPC Applications:



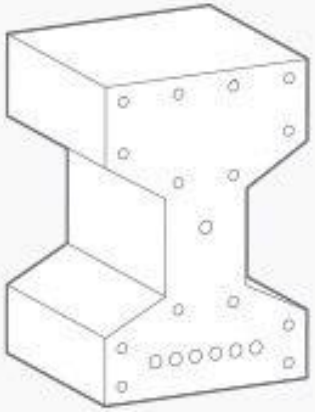
14 in, 94 lb/ft (355 mm, 140 kg/m)
depth, weight

UHPC



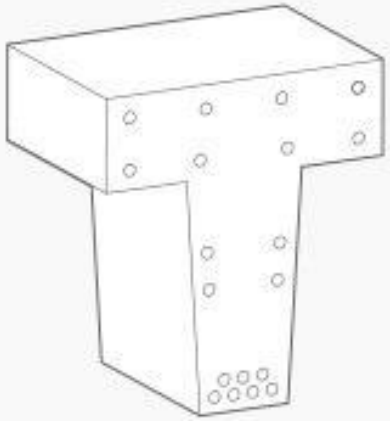
14 in, 75 lb/ft (355 mm, 110 kg/m)

STEEL



28 in, 313 lb/ft (710 mm, 465 kg/m)

PRESTRESSED CONCRETE



28 in, 355 lb/ft (710 mm, 530 kg/m)

REINFORCED CONCRETE

RPC Applications:

RPC Applications:

1. First structure that used RPC was a pedestrian bridge in Sherbrooke, Quebec, **Canada**. span:60 m, **1997**
2. *Seonyu Footbridge on the Han River, Seoul,**South Korea***, span:120 m, ***2002***
3. Qinghai-Tibet R
4. Shawnessy Ligh
5. **An ongoing pro** lly Greek at NSW,

- four traffic lanes
- 16 precast prete al stirrup in the we

Future application of RPC

- This material also has excellent impact resistance properties, and can be employed for hardening military structures or equipment.

- Apart from their exceptional mechanical properties, RPC concretes have an ultra-dense microstructure, giving advantageous waterproofing and durability characteristics. These materials can therefore be used for industrial and nuclear waste storage facilities.

طرح اختلاط نمونه RPC:

مصالح	kg/m^3
سیمان	840
ماسه سیلیسی	930
پودر سیلیس	180
میکروسیلیس	210
فوق روان کننده	40
آب	190

وزن مخصوص بتن تازه: $2400\ kg/m^3$

عمل آوری: 5 روز در آب $90\ ^0C$ و سپس گذاشتن در هوای محیط تا روز آزمایش

مقاومت 28 روزه: $1600\ kg/cm^2$

Thanks for Your Attention